ENERGY CONSERVATION OPTIONS, HOT SPRINGS COVE, B.C.

with special emphasis
on geothermal opportunities

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with special emphasis on geothermal opportunities

Prepared for:

Hesquiat Band Council

Prepared by:

Crippen Consultants
Nevin Sadlier-Brown Goodbrand Ltd.

With a contribution from:

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SUMMARY

This report records the results of a study made to determine the energy conservation options available to the Hesquiat community located at Hot Springs Cove north of Tofino, B.C. and adjacent to the Maquinna Provincial Park hot springs.

The Hesquiat Band Council who commissioned the study were interested in reducing their overall energy burden and in investigating possible geothermal resources and all other energy options available in the area.

The community consists of 24 dwellings, a medical treatment facility and community building housing the school, Band office and shop. A site visit showed that the community's current requirements for electrical energy are met by diesel electric generation using two 60 kW diesel electric generating sets, operating alternately and consuming $25,000 fuel/year. Space heating in the houses is by woodburning stoves and water heating and cooking by bottled gas. The village, first established in 1974, plans to expand slowly as Band members currently residing elsewhere return to live there.

The opportunity for energy savings by upgrading of the houses were examined and repairs to windows, improvements to insulation, air tightness, and wood stove installations were proposed at a cost of $3,000 per house.

Various alternative energy sources were identified for the community and included:

- Expanded diesel-electric generation.
- Development of geothermal resources.
- Generation of electrical energy from a micro hydro installation.
- Thermal generation by wood burning both for space heating and the generation of electrical energy via a steam driven prime mover.
- Electrical generation by wind energy.

The diesel-electric generation option was examined as a base case against which to evaluate other energy supply options. It has the advantage of being a known technology capable of being expanded or contracted in size in accordance to the community needs. Oil is, at present, brought in by ship in bulk.

The expectation of the geothermal energy option, based upon the presence of a natural hot spring close to the village, was extensively examined. Two new hot springs were identified close to the village and, based on evaluation of water and gas samples from these springs and a study of the geology of the area, there is reason to believe that a supply of hot geothermal fluid might be confirmed by drilling. It is likely that this fluid would be best suited to community heating applications rather than electrical generation and the costs of drilling wells to prove the resource would be approximately $300,000. A further $400,000 would then have to be spent to harness and distribute the resources if the drilling proved positive.

The provision of electrical energy from a micro hydro scheme was evaluated. Two potential sites were identified within economic transmission distance of the village. Based on regional hydrological records an evaluation of the power potential of the two sites was made. This showed that the one closest to the village could not supply sufficient energy to meet the long term needs of the community while the more remote site some 10 km away could do so. The capital cost of a 500 kW installation at this second site would be $2,333,000. In addition to supplying all the village energy requirements there exists the possibility of supplying power to an adjacent logging camp until the village's energy needs grow to require the full output of the hydro scheme. At present the logging camp is expending $70,000/yr on fuel for electrical generation.

The possibility of generation of electrical energy from a wood-fired steam driven generator was investigated. No economically available waste wood supply, such as sawmill waste, could be identified and the large wood supply required from natural forests together with the need to staff the operation and maintenance of the system made this option unattractive.

The current practice of space heating using wood stoves was found to be most practical and various recommendations to improve and facilitate the harvesting and distribution of firewood to the houses were made.

The harnessing of wind energy by wind driven electric generation was investigated. The primary load identified for such randomly produced energy was space heating using thermal storage heaters and costs for such a system were approximately $225,000 for the wind generator plus $4,500 per house for the space heating installation.

An economic analysis of the alternatives showed that, should the community decide to increase annual expenditures to make more electrical energy available to meet the energy needs of the village, then the alternative of increased diesel-electric installation and construction of a micro hydro scheme were the most attractive. Increase in annual costs over current expenditures would be approximately $70,000/yr for diesel (with firewood space heating) and $280,000/yr for hydro (with all space heating by electricity).

Generation by wind energy was not found economically attractive and the development costs and risk to prove up the geothermal resource were considered too great to be undertaken by the community alone.

The report sets forth the methods, advantages, disadvantages and costs of increasing the supply of electrical energy so that a decision can be made by the community as to how and when to proceed.

OPTIONS D'ÉCONOMIE D'ÉNERGIE
HOT SPRINGS COVE (COLOMBIE-BRITANNIQUE)

Particulièrement l'énergie géothermique

Résumé

Ce rapport fait état des résultats d'une étude entreprise dans le but de déterminer les options d'économie d'énergie dont peuvent se prévaloir les membres de la communauté Hesquiat située à Hot Springs Cove au nord de Tofino (Colombie-Britannique) et adjacente aux sources chaudes du parc provincial Maquinna.

Le conseil de bande Hesquiat, soucieux de réduire la facture énergétique de la communauté, a commandé l'étude dans le but de définir les ressources géothermiques possibles et toute autre option énergétique disponible dans la région.

La collectivité est composée de 24 habitations, d'un dispensaire et d'un immeuble communautaire qui abrite l'école ainsi que le bureau et le magasin de la bande. Une visite à l'emplacement a permis de constater que deux groupes électrogènes de 60 kW alimentés au diesel et qui fonctionnent tour à tour permettent de satisfaire aux besoins actuels en électricité; ils consomment 25 000 $ de combustible par année. Des poêles à bois assurent le chauffage des locaux tandis que du gaz en bouteille est utilisé pour le chauffage de l'eau et la cuisson. Établi en 1974, le village prendra lentement de l'expansion au fur et à mesure que des membres de la bande qui habitent ailleurs reviennent pour y vivre.

La possibilité de réaliser des économies d'énergie en apportant des modifications aux maisons a été étudiée et on a estimé qu'il en coûterait 3 000 $ par maison pour réparer le fenêtres, améliorer l'isolation et l'étanchéité et installer des poêles à bois.

Diverses options énergétiques ont été examinées:

- production accrue d'électricité au moyen de groupes alimentés au combustible diesel;
- mise en valeur des ressources géothermiques;
- production d'hydro-électricité par une petite installation;
- production d'énergie thermique par la combustion du bois, tant pour le chauffage des locaux que pour la production d'électricité par le biais d'une turbine à vapeur;
- production d'électricité par l'énergie éolienne.

L'option diesel-électricité a servi de scénario de base pour l'évaluation des autres options. Il s'agit d'une technique connue, susceptible d'être augmentée ou diminuée selon les besoins de la collectivité. À l'heure actuelle, le pétrole est acheminé en vrac par navire.

Compte tenu de la présence d'une source chaude naturelle près du village, l'option géothermique a fait l'objet d'un examen exhaustif. Deux nouvelles sources d'eau chaude ont été découvertes près du village et, à partir de l'évaluation de l'eau et du gaz de ces sources ainsi que d'une étude de la géologie de la région, il y a de bonnes raisons de croire qu'un forage puisse confirmer la présence d'une bonne réserve de fluide géothermique chaud. Ce fluide pourrait probablement être plus utile pour le chauffage des locaux que pour la production d'électricité. Les forages de puits nécessaires pour prouver l'amplitude de cette ressource coûteraient environ 300 000 $. Il faudrait ensuite dépenser 400 000 $ pour l'aménager et la distribuer si le forage donnait des résultats positifs.

La possibilité d'aménager une petite centrale hydro-électrique a été évaluée. Deux emplacements, situés à des distances de transmission économique du village ont été identifiés. À partir des dossiers hydrologiques de la région, on a évalué le potentiel hydro-électrique des deux emplacements. Celui qui est situé le plus près du village ne pourrait pas fournir suffisamment d'énergie pour satisfaire aux besoins à long terme de la collectivité tandis que le plus éloigné c'est-à-dire à 10 km pourrait le faire. Il en coûterait 2 333 000 $ pour installer une centrale de 500 kW à ce second emplacement. En vertu de cette option, non seulement pourrait-on satisfaire aux besoins énergétiques du village mais encore serait-il possible de fournir de l'électricité à un camp forestier adjacent jusqu'à ce que toute l'électricité produite soit nécessaire pour satisfaire aux besoins du village. À l'heure actuelle, le camp dépense 70 000 $ par année en combustible pour la production d'électricité.

On a également étudié la possibilité de produire de l'électricité à partir d'un groupe électrogène à vapeur alimenté au bois. On n'a pu trouver aucun approvisionnement économique en rebuts de bois comme les rebuts de scierie et l'importance de l'approvisionnement en bois tiré des forêts ainsi que le besoin d'embaucher du personnel d'exploitation et d'entretien du système rendent cette option peu intéressante.

La pratique courante de chauffer les locaux au moyen de poêles à bois est des plus pratique et diverses recommandations ont été faites pour améliorer la coupe et la distribution du bois de chauffage.

La possibilité de produire de l'électricité à l'aide d'éoliennes à été étudiée elle aussi. La charge primaire d'énergie produite d'une façon si peu constante serait consacrée au chauffage des locaux au moyen de dispositifs de chauffage à stockage thermique; les coûts d'un tel système seraient d'environ 225 000 $ pour l'éolienne plus 4 500 $ par maison.

L'analyse économique des diverses possibilités a démontré que si la collectivité décidait d'accroître ses dépenses annuelles pour produire plus d'électricité afin de subvenir aux besoins du village, l'augmentation de la capacité de l'installation diesel-électrique et la construction d'une petite centrale hydraulique seraient les options les plus intéressantes. L'augmentation des frais annuels serait d'environ 70 000 $ par année pour ce qui est du diesel (avec chauffage des locaux au bois) et de 280 000 $ pour l'installation hydro-électrique (tout le chauffage des locaux étant assuré par l'électricité).

L'utilisation de l'énergie éolienne n'est pas rentable tandis que les coûts de développement et les risques nécessaires pour prouver l'importance des ressources géothermiques sont trop élevés pour que la collectivité les assume seule.

Le rapport énonce les méthodes, les avantages, les inconvénients ainsi que ce qu'il en coûterait d'accroître la production d'électricité de façon que la collectivité puisse prendre une décision éclairée.

Cette étude a été effectuée pour le compte du conseil de bande Hesquiat par les sociétés Crippen Consultants et Nevin Sadlier-Brown Goodbrand Ltd. à l'aide d'une contribution accordée dans le cadre du Programme de démonstration dans les collectivités éloignées d'Énergie, Mines et Ressources Canada.

1. TERMS OF REFERENCE

A Study of the Energy Conservation Options at Refuge Cove Indian Reserve was undertaken by Crippen Consultants in accordance with the terms of reference outlined in Appendix A. The geothermal portion of the Study was carried out by Nevin Sadlier-Brown Goodbrand Ltd.

The terms of reference were set forth by the Hesquiat Band Council and confirmed by the Conservation and Renewable Energy Office of Energy Mines and Resources Canada who participated with the Band in funding the Study.

2. SITE INSPECTIONS

A site inspection was carried out on 2-3 October 1984 by Messrs. H.A. Hutchinson and W. Humer of Crippen Consultants and T.L. Sadlier-Brown of Nevin Sadlier-Brown Goodbrand Ltd. The party was accompanied by Mr. J. Bowen of the Conservation and Renewable Energy office of Energy Mines and Resources Canada and part-time by Mr. V. Amos the Band Manager.

Messrs. Hutchinson, Humer, Sadlier-Brown and Bowen arrived at the Village of Refuge Cove on the evening of 2 October 1984 by water taxi and departed on the afternoon of 3 October 1984 by aircraft.

The existing diesel generating plant and the 25 buildings in the Village were inspected.

A site inspection to the existing hot springs and to the location of two new hot springs was undertaken and water and gas samples were obtained.

A site inspection of a potential hydro generating site was made on the stream at the head of Hot Springs Cove (Site A) and an aerial reconnaissance was made of another potential hydroelectric generating site (Site B) on a stream which flows into Hesquiat harbour approximately 1.2 km east of Hesquiat Point and about 9.5 km west of the Village at Refuge Cove.

On 21-22 November 1984 Messrs. Hutchinson, Sadlier, Brown and Bowen returned to Hot Springs Cove. A meeting was held with the Band members in the evening of 21 November 1984 at Refuge Cove to discuss with them the results of the study. On 22 November 1984 a site inspection of the Hesquiat Point Site (Site B) was made together with a visit to the Greenwood logging camp (see Figure 2).

3. EXISTING INSTALLATIONS

Buildings

The community consists of some 24 domestic dwellings of which three were unoccupied at the time of the visit. In addition there is:

- A community centre building. This is a two storey structure housing the Band Offices and Band operated community store on the ground floor level and the primary school on the upper floor. The school class room is large and used by the community as a meeting hall.

- A medical clinic which has just been completed. It is designed for use by the visiting physician, nurse and dentist.

- A large storage shed adjacent to the floats.

- A small building housing the two diesel electric generating sets which currently supply power to the village.

A plan of the village is shown at Figure 1.

The buildings are all relatively new, the first being built in 1974 and the most recent having just been completed.

Some are in excellent condition while others require improvements to enhance their usefulness and comfort.

Amongst the items requiring attention are:

- Additional insulation, particularly underfloor especially where buildings are constructed on piles and are completely open beneath - See Photo 1.

- Sealing of air leaks into building shells:
  - caulking around windows
  - Door and window seals
  - Holes and openings through walls, floors and ceilings, e.g., around the chimney.

- Repair of broken thermal windows.

- Replacement and cleaning of chimneys from wood burning stoves.

Electrical Installations

Two diesel driven electric generators, each capable of delivering 60 kW, 120/208 VAC, were installed in a separate building. The generators run alternatively, one acting as back up to the other. A 17 hour daily load cycle is used, the generators being started in the morning at 7 a.m. and shut down at midnight by the part-time attendant.

The equipment was installed in 1981 and has approximately 9000 hours operating time on each unit.

Diesel fuel is brought in by barge and currently costs approximately 47¢/litre. The average annual usuage is 54,000 litres ($25,400.00).

Electrical energy is reticulated to the village buildings by overhead conductors and no metering of electrical energy at the consumers premises is undertaken.

At present consumer loads include refrigeration, lighting, and power for electric kettles, toaster, television sets, and other small appliances. Cooking and water heating is fueled by bottled propane and space heating in the houses is by free-standing wood burning stoves. There is no electrical water heating.

The village has 2 satellite TV dishes and the TV signals are distributed to TV sets in individual houses by aerial coaxial cable.

The current electrical load for the community is approximately 50 kW.

4. FUTURE EXPANSION PLANS

The village plans to add further dwellings for band members, who presently reside elsewhere, and detailed plans have been prepared for an additional 9 new individual family houses. The present village layout and proposed future additions are shown on Figure 1.

5. ALTERNATIVE ENERGY SOURCES

5.1 General

The present and future energy needs of the community are evaluated for supply from the following sources:

- Expanded Diesel Electric Generation.
- Energy from Geothermal Sources associated with the hot springs.
- Electrical generation from local micro hydro sites.
- Energy from thermal combustion of wood.
- Other energy sources including wind driven electrical generators and biomass energy sources.

5.2 Diesel Electric Generation

Provision of extra electrical energy by expansion of the existing diesel electric sets has been taken as the base case in the economic analysis carried out when studying the energy options.

Extra and/or larger diesel generating sets could be installed as the load develops. Amongst the advantages of this form of electrical power generation are the following:

- Familiar technology, used in fishing vessels owned by village members.
- High reliability when properly maintained.
- Capacity can be changed in suitable steps as the community's requirements increase (or decrease).

Disadvantages include:

- Reliance on expensive fuel which must be imported to the village. The cost of this fuel is increasing.
- Noise of operation.
- Requirement for daily attendant to start and stop and performance of regular maintenance.

5.3 Geothermal

a. Resource Evaluation

Based on the knowledge of the geology of the region, and on field investigations it is believed there is a good chance that a geothermal resource could be developed.

It is possible that hot water at approximately 110°F could be obtained from a drill hole drilled from a location south of the village towards Mate Island to intersect the fault that lies along the line connecting the existing hot springs and the creek at the head of Hot Springs Cove.

A detailed report on the potential for a geothermal energy resource is attached as Appendix B.

b. Uses for Geothermal Resource

Should such hot water be obtained it could be used for space heating by constructing a hot water distribution system for all buildings in the village or for aquaculture or silviculture being carried out by the Band.

While the possibility exists for generation of electrical energy from hot water using binary cycle system employing a vapour turbine to drive an electrical generator it is not likely that this would be a practical device to use in this location for the following reasons.

The binary cycle turbine is not widely used in North America and its operation and maintenance would require special training and a dedicated operator or operators to be available at the site. Maintenance and repair of the equipment would pose practical problems compared with a diesel electric set because of the general lack of familiarity with it.

Binary turbines are in use at Lakeview, Oregon and elsewhere in the USA but on a somewhat larger commercial scale and the infrastructure for their repair and maintenance is much more readily available than at this remote location.

In any case further investigation to determine temperature, and quantity of geothermal fluids available would be required before any decision could be made and more than one drill hole would probably be required for the practical development of the geothermal resource.

c. Licensing Requirements

Prior to undertaking any drilling investigation the Band should establish right to any resource that might be discovered. The details of the procedures required under the Geothermal Resources Act are set forth in Appendix B.

d. Environmental Impacts

One possible environmental impact of extracting hot water from the geothermal resource could be the decrease in flow from the spring across Hot Springs Cove in the Maquinna Provincial Park.

Thus even if the geothermal resource was proved the amount of hot water that could be extracted might have to be restricted to prevent depleting the Hot Springs.

5.4 Power Generation from Micro Hydro

General

In assessing the opportunities for generating electrical energy from a small hydro installation a map study was first carried out to identify the capacity of watersheds within economical transmission distance of the village. Those sites, whose interconnection with Refuge Cove would have required an underwater cable, were eliminated because of the expense of such an interconnection.

From this study two potential sites were identified, designated Site A and Site B.

During the visits to Refuge Cove field trips were made to both sites and the site access and potential transmission line route were examined. Figure 2 shows the location of the two sites.

Site A

Location

The site is located on an unnamed river at the head of Hot Springs Cove. An intake would be constructed above the waterfall (Photo 3) approximately 1.5 km from the mouth.

The river bed downstream of the falls has been subject to very high debris flows (see Photo No. 4) which appear from aerial observation and air photo analysis to have come from a large slide in the logged area of the watershed shown on Figure 2. Such debris flows pose a hazard to penstock intakes.

The drainage area is limited to 3.3 km^2 and the gross head available is approximately 130 m.

Access

Access to the site can be reached by the existing road along the left bank of the river as far as the village's water supply intake wells. From this point access would have to be constructed along the river bank. There is no docking facility where the road starts at tidewater at the river mouth. (The original Refuge Cove village was located on this site at the river mouth until it was destroyed by a tidal wave several years ago. Some of the existing village buildings still stand on the site.)

Site access can also be obtained from upstream of the proposed penstock intake and upstream of the waterfall by utilizing the existing, and now largely overgrown, logging road that runs from tide water to the logged catchment area, see Fig. 2. Extra access would have to be constructed from the logged area down to the river adjacent to the intake. This logging road has an abandoned barge loading dock at its tidewater end which could be repaired and used for off-loading equipment and machinery.

Layout

The site does not lend itself to construction of significant storage facilities and any installation would, mainly because of the high debris load in the river, have to be based on run of the river flows.

One potential layout would involve a penstock intake on the left bank above the falls with a surface penstock down the left bank to a powerhouse constructed at the bottom of the falls.

Transmission Line

A 4 kV aerial transmission line on wooden poles could be constructed from the powerhouse along the west bank of Hot Springs Cove to the village. This line would follow the right-of-way of the now abandoned Hesquiat-Marktosis telephone line over a portion of its length.

Site B

Location

Site B is located on an unnamed river approximately 1.2 km east of Hesquiat Point and 9.5 km west of Refuge Cove Village. The potential site is approximately 2 km upstream from the river mouth. The watershed has not been logged in the lower reaches adjacent to the potential hydro site. A much larger drainage area, approximately 16 km^2 is available at this location and a gross head of approximately 140 m.

Access

An excellent logging road access is available to within approximately 0.5 km of the site. The logging road access, in use by Greenwood Contractors Ltd., runs from the head of Stewardson Inlet to Boat Basin. There is an excellent dock at Stewardson Inlet for off-loading machinery and equipment.

Access to the site from this logging road would require construction in virgin forest, probably along the left bank of the river upstream from the logging road bridge.

Layouts

It is probable that significant storage would be expensive to provide and again a run-of-the-river plant is proposed. An intake-diversion structure would be required to admit water to the penstock with a powerhouse built against the river bank downstream. The debris load in the river bed is such that careful siting of the intake will be required to prevent it plugging with debris.

Transmission Line

A 12.5 kV aerial transmission line on wooden poles could be constructed from the powerhouse to Refuge Cove again following the line of the abandoned telephone line from Hesquiat to Marktosis. An alternative would be to follow the existing logging road to the point where it follows along the shore of Kanim Lake and then join the old telephone line right-of-way. This would be slightly longer than a direct route but would allow construction alongside the existing logging road for part of the distance and would eliminate an aerial water crossing of Kanim Lake with its attendant expense.

Hydrology

In order to synthesize the hydrology for the two catchment basins a review was made of the data available from Climate Stations and Gauging Stations in the vicinity.

The information available from Climate Stations is shown in Table I and from Water Survey of Canada Gauging Stations in Table 2.

TABLE I
PRECIPITATION

Climate Stations	Elev. m	Total Min Annual Precip. (mm)		*Mean Monthly/Total Mean Annual						#Mean Monthly/Mean of Mean Montly					
				J	F	M	A	M	J	J	A	S	O	N	D
Tofino Airport	20	3288.3	*	0.12	0.11	0.11	0.07	0.04	0.03	0.03	0.03	0.05	0.12	0.13	0.15
49°05' 125°46'			#	1.48	1.34	1.36	0.85	0.52	0.37	0.31	0.42	0.60	1.43	1.58	1.75
Estevan Point @	7	3119.9	*	0.12	0.11	0.10	0.07	0.04	0.04	0.03	0.03	0.06	0.12	0.14	0.14
49°23' 126°33'			#	1.45	1.30	1.24	0.85	0.50	0.44	0.34	0.40	0.70	1.44	1.64	1.72
Tahsis	5	3828.8	*	0.12	0.11	0.09	0.07	0.04	0.03	0.02	0.03	0.07	0.13	0.13	0.16
49°55' 126°39'			#	1.45	1.27	1.10	0.80	0.45	0.37	0.29	0.36	0.85	1.51	1.61	1.94
Carnation Creek	61	2770.3	*	0.14	0.13	0.11	0.06	0.03	0.03	0.02	0.03	0.05	0.10	0.15	0.17
48°54' 125°00'			#	1.63	1.51	1.31	0.67	0.39	0.31	0.25	0.33	0.58	1.24	1.78	1.98

@ 20 km west of Hesquiat Indian Reserve/Hot Springs Cove

TABLE 2
STREAM FLOWS

Water Survey of Canada Gauging Stations	Drainage Area km^2	Mean Annual $m^3/s/km^2$	Mean Monthly/Mean Annual											
			J	F	M	A	M	J	J	A	S	O	N	D
08HB048 Carnation Creek	10.1	0.0807	1.52	1.61	1.47	0.64	0.54	0.32	0.18	0.29	0.37	1.03	1.79	2.31
08HE006 Zeballos River	181	0.1569	1.40	1.07	0.84	0.74	0.81	0.71	0.52	0.38	0.77	1.59	1.49	1.56

From these figures a graph Figure 3 has been prepared comparing precipitation with stream flow for Carnation Creek and Tahsis/Zeballos data. This shows that, on the western side of Vancouver Island, where snowfall is not a large hydrological factor, precipitation mirrors stream flow if viewed as an annual pattern. This is particularly true of Carnation Creek catchment where, for practical purposes the rainfall results in immediate runoff.

The Zeballos catchment is much larger and its upper reaches are subject to snow. Also the Tahsis climatic station (the closest one available to the Zeballos river) is not in the Zeballos catchment but is some 20 km away. The catchment factors result in a delayed response to precipitation and the precipitation-runoff relationship is not as valid as that for Carnation Creek.

Since the catchments being examined for the hydro sites near Refuge Cove are small (16 and 3.3 km^2) and right on the coast they can be considered to have a precipitation-runoff relationship similar to Carnation Creeek. Therefore the Estevan Point pattern of precipiation was used as a basis to produce a characteristic pattern of runoff for the Site A and Site B catchments. Estevan Point is some 20 km west of Hot Springs Cove.

The Carnation Creek climate station receives 2770.3 mm of precipitation annually and the Carnation Creek annual stream flow is 0.815 m^3/sec (2.54 metre/yr). Thus the ratio of runoff/precipitation is 2540/2770.3 or 0.92. Thus for catchments of Sites A and B a similar runoff/precipitation ratio of 0.90 can be assumed.

The Estevan Point annual precipitation is 3199 mm and applying the precipitation ratio of 0.9 the annual runoff of 2800 mm can be computed for the Site A and B catchments. Thus for a unit area of 1 km^2 the mean annual stream flow would be 0.0888 $m^3/sec/km^2$. This has been used to produce the catchment runoff pattern for the Sites A and B catchments as shown on Table 3 below.

TABLE 3
UNIT STREAMFLOWS - SITES A & B

Month	Estevan Pt. Precip. Mean Monthly/ Mean of Mean Monthlies	Streamflow Mean Monthly /Mean Annual	Unit Area Streamflow $m^3/s/km^2$	
Jan	1.45	1.45	0.1288	)
Feb	1.30	1.30	0.1154	)
Mar	1.24	1.24	0.1101	)
Apr	0.85	0.85	0.0755	)
May	0.50	0.50	0.0444	)
Jun	0.44	0.44	0.0391	)- using mean annual
Jul	0.34	0.34	0.0302	) flow = 0.0888 $m^3/s/km^2$
Aug	0.40	0.40	0.0355	)
Sep	0.70	0.70	0.0622	)
Oct	1.44	1.44	0.1279	)
Nov	1.64	1.64	0.1456	)
Dec	1.72	1.72	0.1527	)

From this data the estimated monthly stream flow frequencies (Table 4) and Estimated Daily Flow Durations tabulations (Table 5) have been derived.

TABLE 4
MONTHLY STREAMFLOW FREQUENCY

Month	Mean Monthly Flow $m^3/s/km^2$	Rank	Frequency	% of Time Equalled or Exceeded
Jan	0.1288	3	2.5/12	20.8
Feb	0.1154	5	4.5/12	37.5
Mar	0.1101	6	5.5/12	45.8
Apr	0.0755	7	6.5/12	54.2
May	0.0444	9	8.5/12	70.8
Jun	0.0391	10	9.5/12	79.2
Jul	0.0302	12	11.5/12	95.8
Aug	0.0355	11	10.5/12	87.5
Sept	0.0622	8	7.5/12	62.5
Oct	0.1279	4	3.5/12	29.2
Nov	0.1456	2	1.5/12	12.5
Dec	0.1527	1	0.5/12	4.2

Notes: Mean. Oct-Mar = 0.13 $m^3/s/km^2$ (winter months)
Min. Oct-Mar = 0.11 $m^3/s/km^2$ (winter months)

TABLE 5
ESTIMATED DAILY FLOW-DURATIONS

% of Time Eq. or Exc.	For Coleman Ck. Based on Sarito R. & Carnation Creek: Unit Discharge $m^2/s/km^2$	Ratio to Mean	For Catchment Near Hot Springs Cove with unit mean annual = 0.0888 $m^3/s/km^2$: Unit Discharge $m^3/s/km^2$	
100	0.0004	0.005	0.0004	)
90	0.0080	0.100	0.0089	)
80	0.0168	0.209	0.0186	)
70	0.0283	0.353	0.0313	)
60	0.0435	0.542	0.0481	) - using same ratio
50	0.0609	0.759	0.0674	)
40	0.0811	1.011	0.0898	)
30	0.1058	1.319	0.1171	)
20	0.1391	1.734	0.1540	)
10	0.1872	2.334	0.2073	)

Notes: mean = 0.0802 $m^3/s/km^2$ for Coleman Creek (very close to Carnation Creek's 0.0807)

From these tables the unit area flow-duration curves on both daily and monthly basis have been plotted on Figure 4. From these unit discharges the catchment flows and hence the power available can be calculated as set forth below.

Power Potential of the Sites

The power that may be derived at Sites A and B can be calculated from the relationship:

Power (P) in kW = Hydraulic efficiency (0.93) x turbine efficiency (.87) x generation efficiency (.96) x density (9.8 kN/m^3) x Flow (Q) (in m^3/sec) x gross head H (metres)

Where P = 7.6 Q H kW

Depending upon whether daily or monthly flow duration curves are used the available power (kW) varies.

Tables 6 and 7 below summarize the power available throughout the year.

TABLE 6

POWER AVAILABILITY BASED ON MONTHLY FLOW-DURATION CURVES

% of Time Eq. or Exceeded	SITE A H = 130 m Drainage Area = 3.3 km^2		SITE B H = 140 m Drainage Area = 16 km^2	
	Flow m^3/s	Power kW	Flow m^3/s	Power kW
95	.097	95	.47	500
75	0.14	140	.70	745
60	.22	215	1.05	1115
50	.28	275	1.36	1450
30	.40	395	1.92	2045

TABLE 7

POWER AVAILABILITY BASED ON DAILY FLOW DURATION CURVES

% of Time Eq. or Exceeded	SITE A H = 130 m Drainage Area = 3.3 km^2		SITE B H = 140 m Drainage Area = 16 km^2	
	Flow m^3/s	Power kW	Flow m^3/s	Power kW
95	0.02	20	.09	95
75	0.08	80	.39	415
60	0.16	160	.77	820
50	0.22	215	1.08	1150
30	.39	385	1.87	1990

This information from Table 7 is displayed graphically on Figure 5 for Site A and on Figure 6 for Site B. Superimposed on these figures are the energy requirements with and without electrical heating as determined by the analysis in Section 6 of this report.

It has been established that the optimum installed capacity for a run-of-the-river hydro plant is one that has a design flow equal to approximately the 25% exceedence flow on the flow duration curve. This assumes that the load demand warrants this capacity being installed.

From these figures it may be concluded that:

For Site A

1. The maximum installed capacity available at the site would be 400 kW (27.5% exceedence).

2. There is insufficient capacity to meet the year 2000 load with electric heating (500 kW).

3. The minimum winter power availability of some 350 kW, based on the water flows available, is sufficient to meet the 1985 peak requirements including electric heating.

4. There is sufficient capacity to meet the Year 2000 demand without electric heating approximately 45% of the time. Beyond this diesel generation would be required and since this demand is 260 kW diesel capacity up to this value would have to be installed.

5. Site A is not capable of meeting peak load demands even if electrical heating is excluded and supplementary diesel generating capacity would be required.

6. The capital cost of a single 400 kW unit utilizing a Banki turbine and including 4 kV transmission line is estimated to be C $1,160,000 in 1985 dollars.

For Site B

1. The maximum installed capacity available at the site would be 2200 kW (25% exceedence). This potential load demand does not warrant this capacity being installed.

2. There is sufficient peak capacity available to meet the Year 2000 electrical loads including electrical heating (500 kW). Therefore a single 500 kW unit installation would be appropriate. The capital cost of installing such a scheme is estimated to be $2,333,000 in 1985 dollars.

3. The difference in load between the Year 2000 requirement and the 1985 peak electrical load with electric heating (236 kW) is 264 kW which would be available for sale to the logging camp, until load growth at the village required it there. (See Page 5-15 Other Potential Customers.)

4. The minimum winter power availability is approximately 1900 kW, based on the water flows available. Thus sufficient peak power is available for winter electrical heating without recourse to supplementary diesel.

Other Potential Customers

During the site inspection of Site B discussions were held with Greenwood Contractors at their camp at the head of Stewardson Inlet. This logging camp is currently supplied with electric power from two 60 kW diesel generating sets consuming approximately $70,000 fuel/year. The camp expects to have a 20 year life and the possibility therefore exists of supplying the camp with power in addition to the Refuge Cove Village.

To do this a branch transmission line would be required off the main line branching down the road at the side of Kanim Lake (See Fig. 2). This 12.5 kV line, 3.2 km long and associated switchgear would cost approximately $138,000.

The opportunity therefore exists to sell power to the logging camp, probably at an avoided power cost of 15¢/kwh for a period of up to 20 years.

Should the hydro option be proceeded with the extent and value of this potential market, and its longer term existence, should be examined in detail.

Environmental Aspects

The principle environmental impact of the proposed hydro installation will be on the fisheries resources. Both streams proposed for development have salmon spawning in their lower reaches and environmental impact studies would be required to ascertain that development could proceed without significant fisheries impact.

The Site A location upstream of the falls is probably higher than fish can travel up river and therefore only the powerhouse location and the access road would require careful siting to minimize disturbance to the river bed.

In the case of Site B it is not known how far upstream the salmon travel and siting of intake, powerhouse and access road would all have to be done so as to mitigate any impact on the river regime. These questions would be addressed in more detail if the hydro generation option was to proceed.

Cost Estimates

Based on information contained in the EMR Micro Hydro Guidance Manual of Procedures for Assessment of Micro Hydro Potential and using internal cost updates for this document and costs of recent small hydro projects it is estimated that the capital cost of developing the sites would be as follows.

Site A

400 kW Single Machine		$
1.	Intake	70,000
2.	Penstock	166,000
3.	Powerhouse	482,000
4.	Transmission line and switchgear km 4 kV	90,000
5.	Road access to powerhouse penstock and intake	71,000
6.	Engineering and management	88,000
7.	Contingency @ 20%	194,000
		1,161,000

Site B

500 kW Single Machine		$
1.	Intake	70,000
2.	Penstock	498,000
3.	Powerhouse	507,000
4.	Transmission line to village, including switchgear 12.5 kV 10.5 km	455,000
5.	Road access to powerhouse penstock and intake	237,000
6.	Engineering and management	177,000
7.	Contingency @ 20%	389,000
		2,333,000

	$
Extension of transmission line to Stewardson Inlet 3.2 km @ 12.5 kV including switchgear	138,000

5.5 Thermal Generation

Two modes of thermal generation were examined, the use of thermal energy for space heating and the use of thermal energy to generate electricity.

a. Thermal Space Heating

The current practice of burning wood in individual residential wood stoves is the optimum thermal space heating system for this location. Any form of community furnace and distribution system such as hot water would be less cost efficient than the individual systems now in place because of the small number of houses involved.

If this system of space heating is to be continued certain improvements could be instituted. These would include:

- Repair and replacement of some of the wood stove chimney systems to bring them into conformity with the current fire safety code.

- Installation of a more efficient fire wood gathering, hauling, cutting and splitting operation. This would involve supply of felling equipment, chain saws, log hauling equipment and a mechanized firewood delivery system such as a tractor and trailer combination. At present there are no vehicles in the village except rubber tired tractors and few roads on which to haul materials. There appears to be an adequate firewood supply on the reserve land behind the village and across the inlet.

b. Thermal Electric Generation

Generation of electrical energy from woodburning requires provision of a boiler and a prime mover such as a steam turbine or reciprocating steam engine to drive the electric generator. In addition the fuel gathering requirements outlined above would have to be installed since there is no readily available waste wood source such as sawmill waste.

Fuel for such an installation could come from local woodland sources and a logging, cutting, splitting operation, somewhat more extensive than that required for individual domestic firewood supplies would be required.

It is estimated that to supply the entire energy needs of the village from a wood burning electric generation some 13.2 ha (32.7 acres) of local forest would be consumed each year.

A qualified operator or operators would be required on a continuous basis to operate the steam boiler and prime mover in addition to those engaged in wood supply.

5.6 Other Energy Sources

a. Wind Energy

Availability

Previous studies have indicated that many coastal locations in British Columbia show a good wind energy potential. The usual measure of wind potential used is the mean annual wind speed and locations of interest for wind generation should have a value of about 24 km/h. The other important aspect is the matching of the available wind with the energy requirements. Coastal communities have the greatest energy need in the winter when the conventional fuel/energy consumption such as space heating and lighting is highest, which is also when the wind energy is most readily available. Wind energy may also be determined from wind speed/duration data on a monthly basis indicating the amount of time that the wind exceeds certain speeds. This data would provide the amount of wind energy available for a certain percentage of time. Wind speed recordings on a continuous basis over long periods, of the order of a year, would be required.

Technology of Systems

Wind energy systems have historically been used for pumping of water, milling and mechanical power applications. Wind energy systems providing electric power were less widespread and were generally of small size. The increase of energy costs for conventional power sources in recent years together with modern and inovative technology have increased the size of available wind turbines.

At present the cost of equipment for vertical axis machines varies from approximately $2,500 per kW for a 100 kW unit to approximately $3,500 per kW for smaller units.

Application at Refuge Cove

Various possible sites would have to be monitored for approximately one year in order to establish the energy availability pattern and hence the economical size of generator.

Because of the intermittent output of a wind generator the most useful application at Refuge Cove would be for storage heating. Electrical storage heaters could be installed in residences and would operate directly from the wind driven generator and store heat when wind energy was available. Heat storage systems typically used in solar heating applications but using an electrically heated hot water tank as a heat storage medium would be applicable. This type of resistive load requires a synchronous rather than an induction generator.

The wind farm installations in California are working on an investment basis and it can be assumed that power is generated/sold to the power utility at competitive rates. It must be noted that these generators are induction generators, lower in cost, but only suitable for connection to a relatively large electrical system.

In case of the Refuge Cove site synchronous generator(s) would be required and should be used to generate energy for heating and not be connected directly to the relatively small diesel generator(s).

An energy cost of $0.15 to $0.40 per kWh can be expected depending on the size of selected unit.

The extent to which wind generation could be used to replace firewood space heating could only be determined after on site wind measurements were carried out for a period of 1 year.

However assuming a 75 kW heating load the capital cost of the generator would be $225,000 and to this a cost of $4,500/house should be added for supply and installation of storage space heaters.

b. Bio-mass Generation

The provision of energy from the degeneration of biological material was considered. Typically this utilizes animal wastes or vegetation in a biological process which produces combustible gas, such as methane.

The gas is often collected and used directly for cooking and space heating.

Given the energy requirement at Refuge Cove no adequate source of fuel for a bio-mass generator can be readily identified.

c. Waste Heat Recovery

If the present diesel generating system remains in use there is the potential for recovering waste heat from the engine and using it to heat the community centre building. This would require the fitting of a heat exchanger with diverter to the engines radiator system, the provision of insulated piping from the generator building to the adjacent community centre (see Fig. 1) and the installation of a recovery heat exchanger coil in the buildings existing hot air furnace. It is estimated that some 15 kW of energy could be obtained. The capital cost of the installation would be $9,000 and the annual savings have been computed at $1,500/yr. Incremental operating costs would be negligible. The current expenditure in furnace oil for this building is $2,500/yr. It would also be practical to modify the exhaust system at minimal cost to reduce the noise level from the diesels when they are operating. The exhaust would be ducted to a covered pit thus forming a large expansion muffler. Minimal improvements to the generator building would also improve the soundproofing.

5.7 Summary of Energy Supply Options

Prior to considering economic comparisons between the energy supply alternatives the options available are summarized as follows:

a. Supply by Diesel Electric Generation

This option has a high and escalating fuel cost but allows increase of capacity in increments to suit the load growth. It is a proven technology well understood in the village and one that has moderate maintenance costs easily met from existing facilities in the area.

b. Supply from a Small Hydro Installation

This option has a high capital cost and would require the installation of the total capacity required of the system. It is a proven technology, with low maintenance costs and a suitable site capable of supplying all the village's requirements existing relatively close by.

c. Supply from Geothermal Resources

This option probably exists but would require considerable capital expenditures for drilling to confirm its existence. Such expenditures could well be made without any energy supply resulting from them.

If geothermal hot water is located its most likely application is for community heating. Other electrical needs such as lighting, electric motors and cooking facilities would still have to be supplied by other generation means, probably diesel-electric generation. Depending on the

temperature of the geothermal water a binary cycle turbine might be employed to drive a generator to supply electrical energy. The binary cycle turbine is not a common turbine and its maintenance would prove more difficult than for instance a conventional diesel engine. Because of the uncertainty as to whether the geothermal resource would be suitable to generate electrical energy it has been considered as a source of space heating only in the economic analysis.

d. Supply by Direct Thermal Conversion (Wood Burning)

This option, currently in use at the village for space heating, could be extended and the wood supply system streamlined. Electrical energy for lighting, electric motors, and cooking would still have to be suplied by other sources. The generation of electrical energy by a wood fired steam engine would require large quantities of timber. It is however a proven technology but would require an attendant or attendants with appropriate technical qualifications to operate the system. For these reasons this option has not be considered further.

e. Supply by Wind Generation

This option, which would supply electrical energy from a wind driven generator, would provide energy only when the wind is blowing. Its most useful application in the community is for electrically driven storage heating for space heating or water heating. It has a high capital cost, may be installed in increments of capacity and is a new but reasonably well proven technology. Maintenance requirements are moderate and the equipment is less familiar and hence less easy to service than for instance diesel generating equipment.

6. ECONOMIC ANALYSIS

Economic analysis has been carried out and financial cash flows have been prepared using continuation of existing and the most promising development options. In each scenario community growth and inflationary effects have been taken into account. Unit energy costs are also calculated in constant (1984) dollar values.

Case 1

Called the base load case, this assumes continued use of the present energy supply situation consisting of diesel generation with electrical load restrictions which exclude the use of electric stoves, electric water heating or electric space heating, and continuation of wood burning for space heating. The analysis considers only the cost of diesel electric generation and makes no financial allowance for the cost of space heating by firewood.

Case 2

This development option assumes generation of all foreseeable electrical requirements by diesel coupled with the continuation of space heating by wood burning stoves. Present diesel generating facilities are assumed to be upgraded in 1985 with sufficient capacity to allow the use of electric stoves, dishwashers, electric water heaters, and other previously restricted equipment. As in Case 1 the costs of space heating by firewood are not included in the analysis; the cost of the diesel-electric generation only is given.

Case 3

This development option assumes the provision of all electrical power requirements (without restriction) as outlined in Case 2 plus the addition of electric space heating, all supplied with electricity generated by a micro hydro installation.

Case 4

In this development option space heating is assumed provided from geothermal sources by distribution of piped hot water throughout the community. The cash flow cost sheet refers only to the additional costs (incremental costs over and above Case 1, 2 or 3 generation costs) required to install and operate the geothermal system. The costs shown in Case 4 must therefore be added to the electrical generation costs for either of the Cases 1 to 3 above. They represent the costs of space heating from the geothermal source.

In preparing this analysis the following assumptions were made.

1. 5% per annum inflation has been applied to all costs including diesel fuel.

2. Annualized Capital Costs are based on debt retirement over replacement interval, borrowing cost 10% per annum.

3. Amortization of major capital cost outlays is assumed over 15 year period with 10% per annum borrowing cost.

4. Constant $ costs based on de-escalation of inflated costs at 5% per annum.

5. Case 1
   1 new house per year load growth
   1 new diesel set at end 1988
   1 new diesel set at end 1995
   major overhauls are included in O & M

6. Case 2
   1 new house per year load growth
   1 new diesel set at end 1985
   1 new diesel set at end 1993
   major overhauls are included in O & M

7. Case 3
   1 new house per year load growth
   existing diesel plant retained for standby and supplementary generation during summer months - (note supplementary diesel will be required in summer months only when there is no heat load)

8. Case 4
   Incremental cost only of geothermal heating is shown.

Capital Cost	$ 300,000	drilling
	$ 300,000	piping (3 km of 100 mm Ø insulated)
	$ 40,000	heat pump
	$ 60,000	retriculation
	$ 700,000	

The analysis of these 4 cases is summarized in Tables 8, 9, 10 and 11.

TABLE 8

	PEAK CAPACITY DEMAND	ANNUAL ENERGY DEMAND	CAPITAL COST	DIESEL FUEL COST	O&M	ANNUALIZED CAPITAL COST	TOTAL ANNUAL COST (Inflated $)	UNIT ENERGY COST (Inflated $)	TOTAL ANNUAL COST (Constant $)	UNIT ENERGY COST (Constant $)
	kW	kWh	$	$	$	$	$	c/kWh	$	c/kWh
1985	54	168,000	500	26,262	2,800	500	29,562	17.6	29,562	17.6
1986	58	181,000	500	29,709	2,900	500	33,109	18.3	31,532	17.4
1987	63	195,000	600	33,607	3,100	500	37,207	19.1	33,748	17.3
1988	67	209,000	31,000	37,821	4,900	500	43,221	20.7	37,336	17.9
1989	72	224,000	700	42,562	6,200	7,070	55,832	24.9	45,933	20.5
1990	77	240,000	700	47,882	6,600	7,070	61,552	25.6	48,228	20.1
1991	82	257,000	800	53,838	6,900	7,170	67,908	26.4	50,674	19.7
1992	88	275,000	800	60,489	7,300	7,170	74,959	27.3	53,272	19.4
1993	94	294,000	900	67,901	7,500	7,270	82,671	28.1	55,955	19.0
1994	101	314,000	900	76,147	7,900	7,270	91,317	29.1	58,864	18.7
1995	107	335,000	65,300	85,301	7,500	7,370	100,171	29.9	61,496	18.4
1996	115	357,000	1,100	95,448	17,500	18,325	131,273	36.8	76,753	21.5
1997	122	380,000	1,200	106,677	10,500	18,425	135,602	35.7	75,509	19.9
1998	130	405,000	1,300	119,380	11,000	18,525	148,905	36.8	78,968	19.5
1999	138	430,000	1,400	133,087	11,500	18,625	163,212	38.0	82,433	19.2
2000	147	457,000	1,500	148,516	12,100	18,725	179,341	39.2	86,266	18.9

Notes:
1. Inflation 5% p.a.
2. Annualized capital costs based on amortization over period between major outlays, 10% interest rate.

CASE 1 - PRESENT RESTRICTED LOAD
DIESEL GENERATION
FIREWOOD SPACE HEATING

TABLE 9

	PEAK CAPACITY DEMAND	ANNUAL ENERGY DEMAND	CAPITAL COST	DIESEL FUEL COST	O&M	ANNUALIZED CAPITAL COST	TOTAL ANNUAL COST (Inflated $)	UNIT ENERGY COST (Inflated $)	TOTAL ANNUAL COST (Constant $)	UNIT ENERGY COST (Constant $)
	kW	kWh	$	$	$	$	$	c/kWh	$	c/kWh
1985	90	394,000	40,500	61,590	5,700	500	67,790	17.2	67,790	17.2
1986	97	425,000	500	69,758	7,400	8,000	85,158	20.0	81,103	19.1
1987	104	458,000	600	78,934	7,600	8,100	94,634	20.7	85,835	18.7
1988	113	493,000	600	89,214	8,100	8,100	105,414	21.4	91,060	18.5
1989	121	529,000	700	100,515	8,500	8,200	117,215	22.2	96,433	18.2
1990	130	568,000	700	113,321	8,800	8,200	130,321	22.9	102,110	18.0
1991	139	608,000	800	127,367	20,100	8,300	155,767	25.6	116,236	19.1
1992	149	650,000	800	142,974	9,800	8,300	161,074	24.8	114,472	17.6
1993	160	696,000	60,900	160,746	13,400	8,400	182,546	26.2	123,555	17.8
1994	172	745,000	900	180,666	14,100	13,200	207,966	27.9	134,057	18.0
1995	184	797,000	1,000	202,940	14,800	13,300	231,040	29.0	141,839	17.8
1996	198	852,000	1,100	227,792	15,600	13,400	256,792	30.1	150,141	17.6
1997	212	912,000	1,200	256,026	16,200	13,500	285,726	31.3	159,103	17.4
1998	278	976,000	1,300	287,692	32,300	13,600	333,592	34.2	176,911	18.1
1999	244	1,044,000	1,400	323,123	34,000	13,700	370,823	35.5	187,291	17.9
2000	262	1,117,000	1,500	363,003	18,000	13,800	394,803	35.3	189,907	17.0

Notes:
1. Inflation 5% p.a.
2. New diesel units in 1st year and 9th year
3. Annualized capital costs based on amortization over period between major outlays, 10% interest rate.

CASE 2 - NO LOAD RESTRICTION
DIESEL GENERATION
FIREWOOD SPACE HEATING

TABLE 10

	PEAK CAPACITY DEMAND	ANNUAL ENERGY DEMAND	CAPITAL COST	DIESEL FUEL COST	O&M	ANNUALIZED CAPITAL COST	TOTAL ANNUAL COST (Inflated $)	UNIT ENERGY COST (Inflated $)	TOTAL ANNUAL COST (Constant $)	UNIT ENERGY COST (Constant $)
	kW	kWh	$	$	$	$	$	c/kWh	$	c/kWh
1985	236	914,000	2,333,000						NA	NA
1986	248	965,000	0	1,716	20,000	305,623	327,339	33.9	311,751	32.3
1987	261	1,018,000	0	2,072	21,000	305,623	328,695	32.3	298,136	29.3
1988	275	1,073,000	0	2,502	22,050	305,623	330,175	30.8	285,218	26.6
1989	289	1,129,000	0	3,021	23,153	305,623	331,797	29.4	272,970	24.2
1990	304	1,180,000	0	3,647	24,310	305,623	333,580	28.3	261,369	22.1
1991	318	1,248,000	0	4,405	25,526	305,623	335,554	26.9	250,396	20.1
1992	334	1,310,000	0	5,318	26,802	305,623	337,743	25.8	240,028	18.3
1993	350	1,376,000	0	6,422	28,142	305,623	340,187	24.7	230,252	16.7
1994	368	1,445,000	0	7,756	29,549	305,623	342,928	23.7	221,054	15.3
1995	386	1,517,000	0	9,365	31,027	305,623	346,015	22.8	212,423	14.0
1996	405	1,592,000	0	11,308	32,578	305,623	349,509	22.0	204,351	12.8
1997	425	1,672,000	0	13,654	34,207	305,623	353,484	21.1	196,833	11.8
1998	446	1,756,000	0	16,487	35,917	305,623	358,027	20.4	189,869	10.8
1999	468	1,844,000	0	19,908	37,713	305,623	363,244	19.7	183,463	9.9
2000	492	1,937,000	0	24,040	39,599	305,623	369,262	19.1	177,621	9.2

Notes:
1. Inflation 5% p.a.
2. Annualized capital cost based on amortization over 15 years at 10% interest rate.

CASE 3 - NO LOAD RESTRICTION
SMALL HYDRO GENERATION
SPACE HEAT BY HYDRO

TABLE 11

	PEAK CAPACITY DEMAND	ANNUAL ENERGY DEMAND	CAPITAL COST	DIESEL FUEL COST	O&M	AMORTIZATION COST	TOTAL ANNUAL COST (Inflated $)	TOTAL ANNUAL COST (Constant $)
	kW	kWh	$	$	$	$	$	$
1985		12,500	700,000					
1986		13,000		2,134	10,500	92,000	104,634	99,651
1987		13,500		2,327	11,000	92,000	105,327	95,534
1988		14,000		2,533	11,600	92,000	106,133	91,682
1989		14,500		2,755	12,200	92,000	106,955	87,992
1990		15,000		2,993	12,800	92,000	107,793	84,458
1991		15,500		3,247	13,400	92,000	108,647	81,074
1992	Negligible	16,000		3,519	14,100	92,000	109,619	77,904
1993		16,500		3,811	14,800	92,000	110,611	74,866
1994		17,000		4,123	15,500	92,000	111,623	71,953
1995		17,500		4,456	16,300	92,000	112,756	69,222
1996		18,000		4,813	17,100	92,000	113,913	66,602
1997		18,500		5,194	18,000	92,000	115,194	64,144
1998		19,000		5,601	18,900	92,000	116,501	61,783
1999		19,500		6,035	19,800	92,000	117,835	59,515
2000		20,000		6,500	20,800	92,000	119,300	57,385

Notes:
1. Inflation 5% p.a.
2. Energy and costs shown in this table are for installation and operation of geothermal facility only. Diesel generation is assumed.
3. Capital cost amortized over 15 years at 10% interest rate.

CASE 4 - SPACE HEAT BY GEOTHERMAL

The results of the cash flow analysis are summarized on Figure 7 Annual Cash Flow, Figure 8 Incremental Cash Flow (for Geothermal heating) and Figure 9 Unit Energy Cost. The following conclusions can be drawn from the analysis:

a. On an annual cash flow basis, the least expensive option is to continue with the status quo (Case 1) ($30,000/yr 1985) or move to Case 2 at approximately double the cost of Case 1 ($68,000/yr 1985). The benefits to be obtained from the additional costs will be unrestricted use of electric water heaters and electric stoves and household appliances such as dishwaters.

b. Investment in Case 3 involves a commitment to a large capital expenditure $2,333,000 and a commitment to maintain and operate a hydro plant which will be located some distance from the community, with supplementary diesel plant which will also serve as an emergency power source if the hydro plant is down. The benefits of investment in hydro may be anticipated with confidence: once the capital investment is made, the recl cost of debt retirement and O & M will likely diminish with time despite the increase in load growth.

c. Investment in Case 4 involves an element of risk in that considerable capital investment of $700,000 is required, some $300,00 of which would be in exploratory drilling to confirm the availability of the resource. It also involves a commitment to maintain and operate approximately 3 km of piping with associated pumps, and a heat pump facility which will be required to extract heat energy from the geothermal water. If however, the resource is available, and it is adequately maintained, the benefits may be anticipated with confidence: once the capital investment is made, the real cost of debt retirement and O & M will likely diminish with time despite the increase in load growth.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Repairs to Houses

The Village of Refuge Cove has a mild climate and the lifestyle (fishing) of the community makes impractical any consideration of major thermal retrofit of the housing. However, regardless of the method of energy supply chosen a program of minimum repair to individual houses should be carried out as outlined in Section 3 in order to conserve energy. It is estimated that the cost of these repairs would average $3,000 per house.

To expedite the work it is recommended that a single individual, skilled in such work, be retained on contract to direct the repairs and that he hire local labour to work under his direction. This system has worked well in the community as evidenced by the construction of the most recent residence which resulted in a high quality building, constructed efficiently and in a minimum time.

The estimate of $3,000 is based on such an arrangement and includes an allowance for materials and wages for both the contractor and locally hired staff at union rates.

7.2 Improvements to Firewood Gathering Facilities

It is recommended that an improved system of firewood gathering be developed if the use of firewood for space heating is to continue. This would include provision of equipment for felling timber, a small tracked dozer with winch for hauling firewood logs and by improved facilities, for cutting and mechanically splitting the wood. A trailer, for attachment to the village's rubber tired front end loader is also recommended to facilitate distribution of the split firewood.

These facilities could be integrated with the current village sawmill operation. A minimum amount of equipment including a hydraulic log splitter and a rubber tired trailer for the front end loader would cost $10,000.00.

7.3 Construction of Hydro Plant vs Diesel Plant

Two alternative hydroelectrical generation development options have been examined for comparison against continuation of the present diesel system with load restrictions (base case). The community can either increase the capacity of its existing diesel generation facilities to satisfy unrestricted electrical demand, or it can install a micro hydro generating plant and retain a diesel standby which will meet unrestricted electrical demand and further meet all space heating requirements in the community.

Each alternative will require commitment to increased annual expenditures on electrical energy, the benefits being removal of present restrictions on the use of electrical equipment, and in the hydro case, elimination of the need to gather firewood for space heating. If the community makes the decision to accept higher annual expenditures in order to remove electrical demand restrictions then consideration should be given to diesel generation (Case 2) and hydro generation (Case 3); in the latter (hydro) option, sufficient energy

will be available for space heating and the higher costs of hydro will be offset by the benefit of eliminating wood fired space heating. Selection of the diesel or hydro alternative will therefore depend on financing and economic criteria which are beyond the scope of this report. In broad terms however, the increase in costs over and above the base case for diesel generation will be $70,000/year and for hydro generation $280,000/year. The approximate increase in costs which can be attributed to the provision of electrical as opposed to wood fired space heating will be the difference between the two above figures, which is approximately $210,000/year.

7.4 Further Investigation of Geothermal Resource

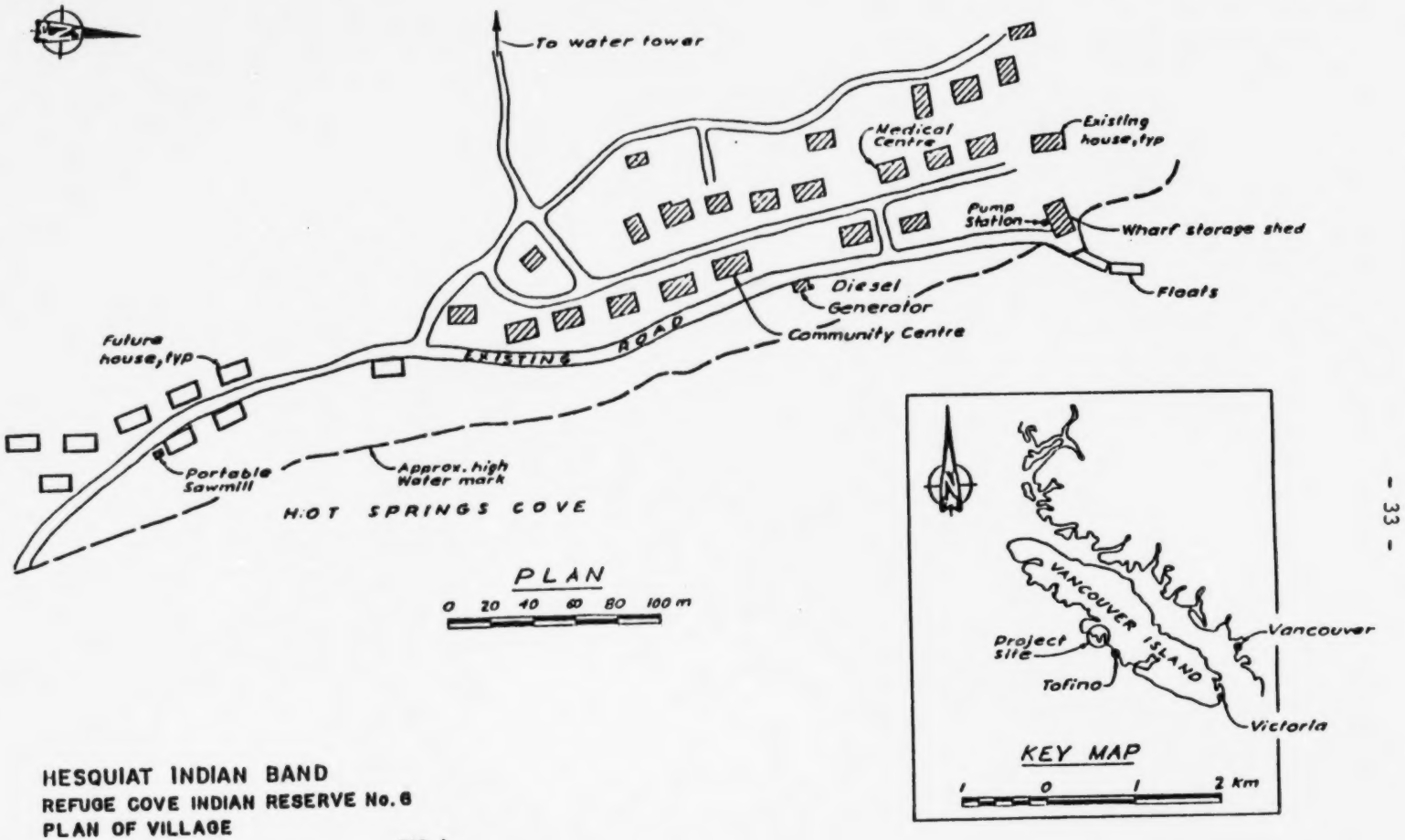
In view of the favourable indications for geothermal energy further investigations of this resource are recommended.

A drill hole would be required in an area south of the village as recommended in Appendix B, paragraph 3.4. It is estimated that the cost of this work would be approximately $145,000. Should funding of this magnitude be unavailable two less expensive options are suggested in Annex B, Pages 15 and 16. The first, costing approximately $100,000, would involve drilling three shallow holes which would produce valuable geological and geothermal information but would not produce hot fluids on a production basis. The second alternative, costing approximately $34,000, would involve a detailed study of the surface geology without drilling and would only provide information for use in future drilling programs.

However in view of the investigative nature of the project it is recommended that the Band only pursue it if initial funding from other sources can be obtained. Should this be done and the initial results prove positive then the Band should consider investing its own funds in the development phase.

FIGURES

FIGURE 1



HESQUIAT INDIAN BAND
REFUGE COVE INDIAN RESERVE No. 6
PLAN OF VILLAGE

FIG. 1

FIGURE 2

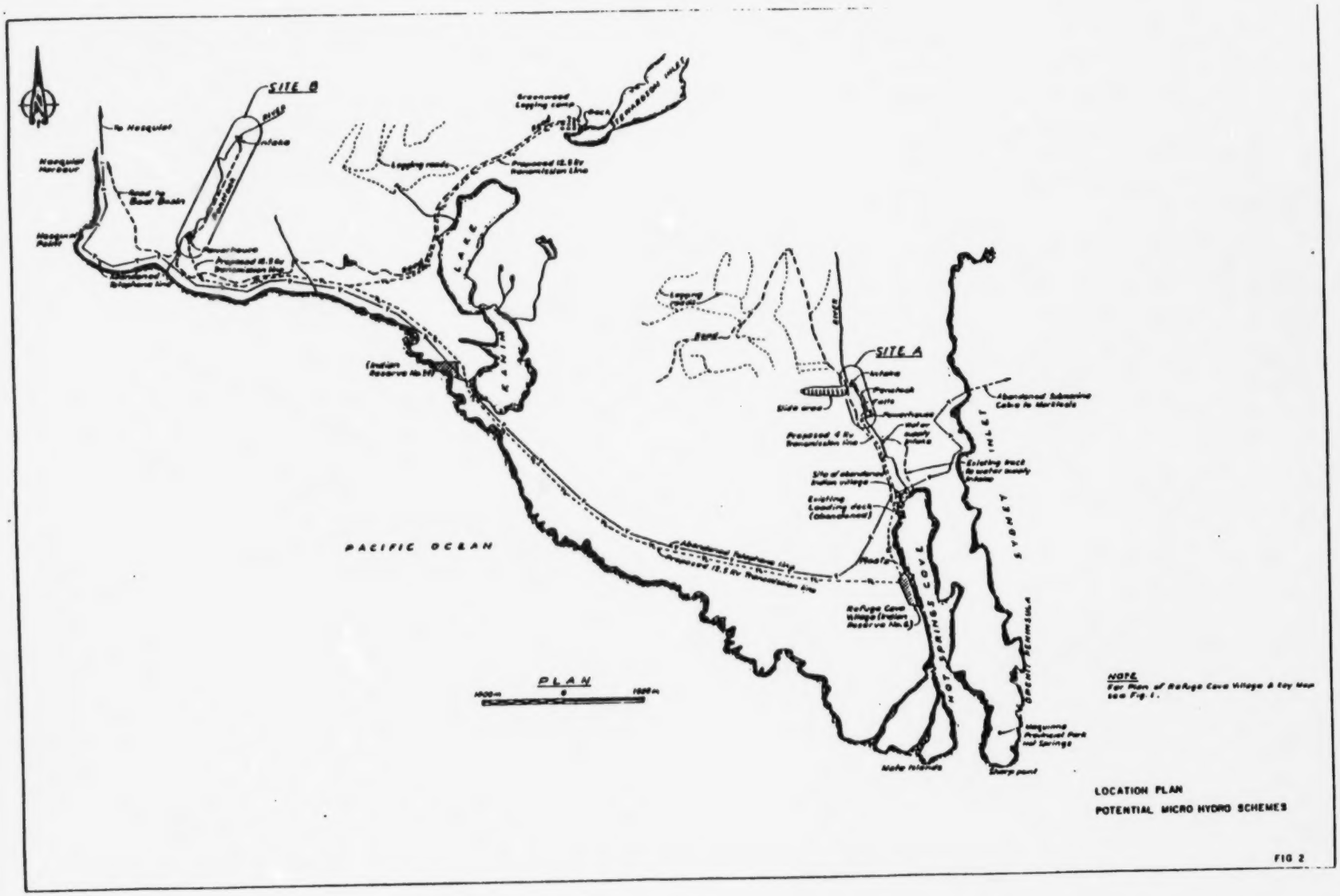

SITE B
SITE A
PACIFIC OCEAN
PLAN
NOTE
LOCATION PLAN
POTENTIAL MICRO HYDRO SCHEMES
FIG 2

FIGURE 3

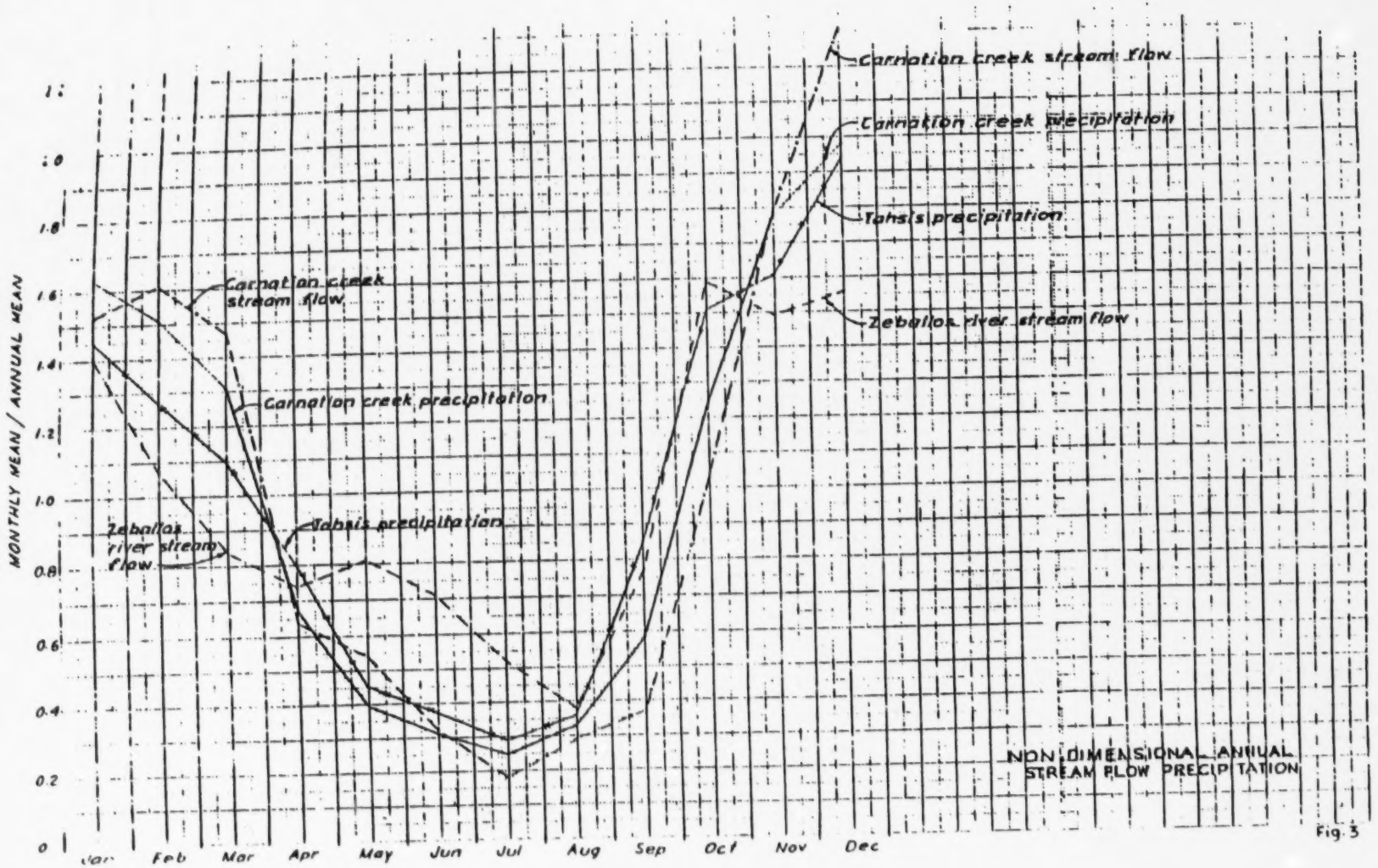


Fig. 3

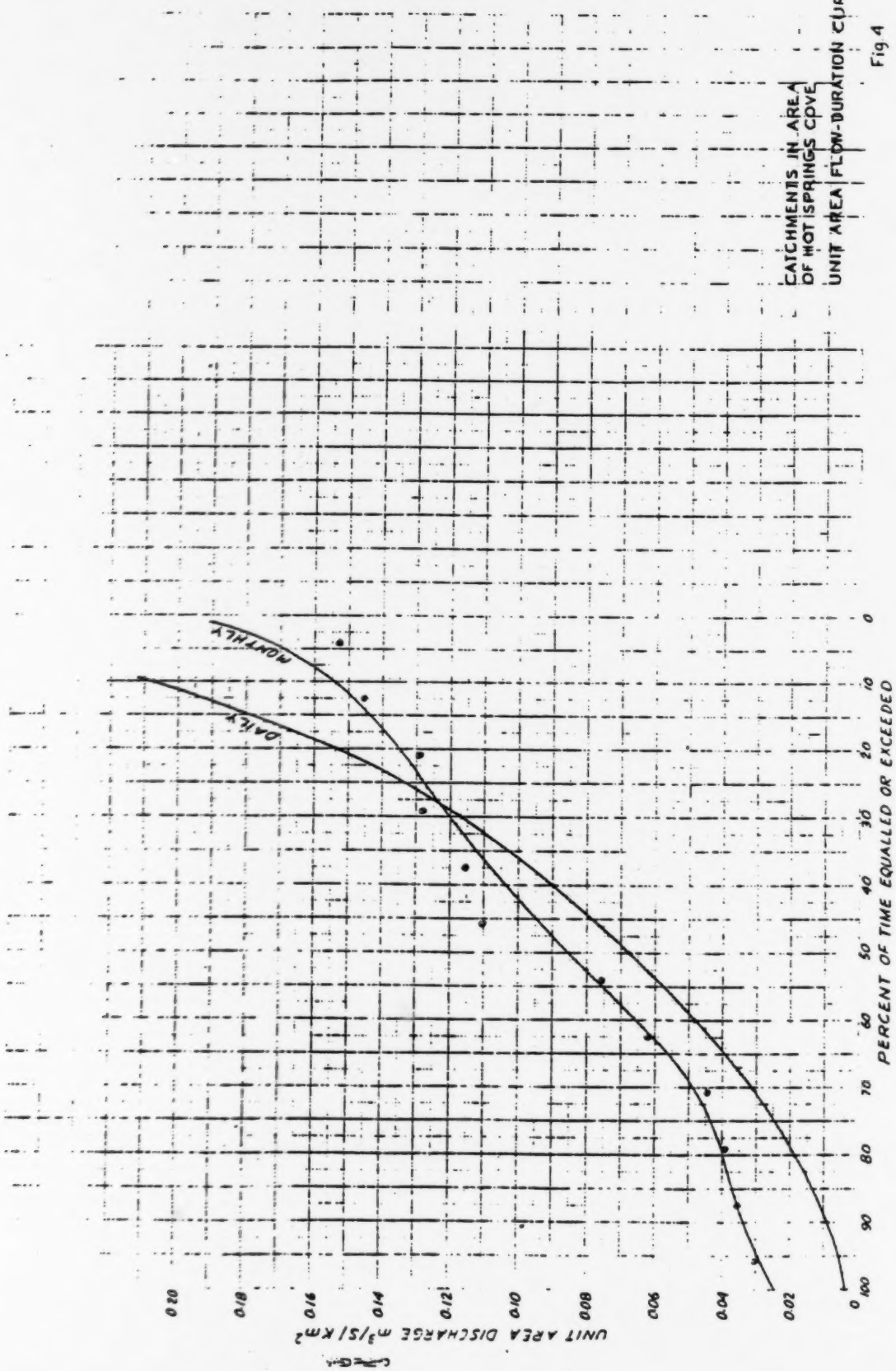
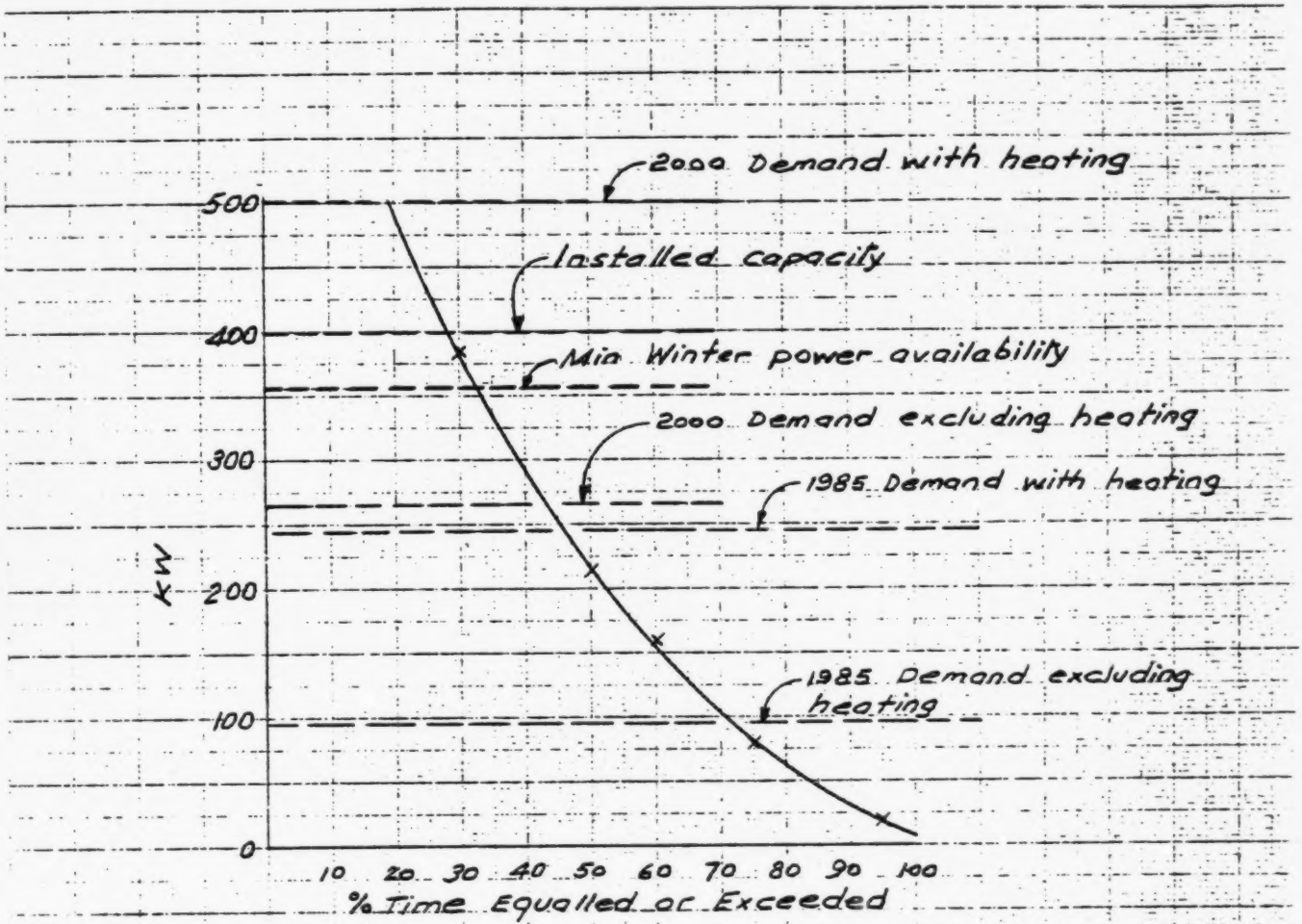
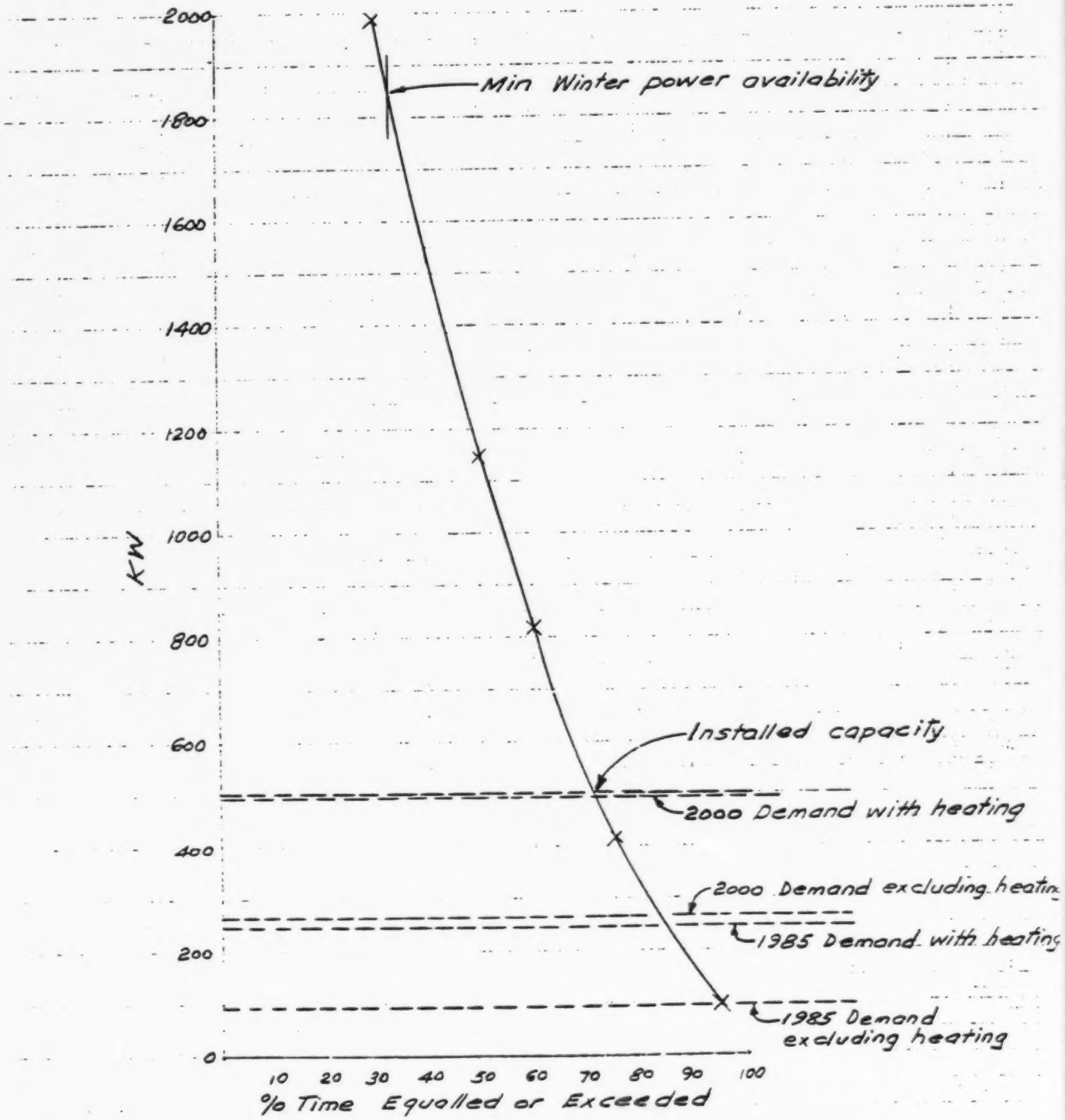

CATCHMENTS IN AREA OF HOT SPRINGS COVE
UNIT AREA FLOW-DURATION CURVES
Fig 4
MONTHLY
DAILY
UNIT AREA DISCHARGE m³/S/KM²
PERCENT OF TIME EQUALLED OR EXCEEDED
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
10
20
30
40
50
60
70
80
90
100

FIGURE 4



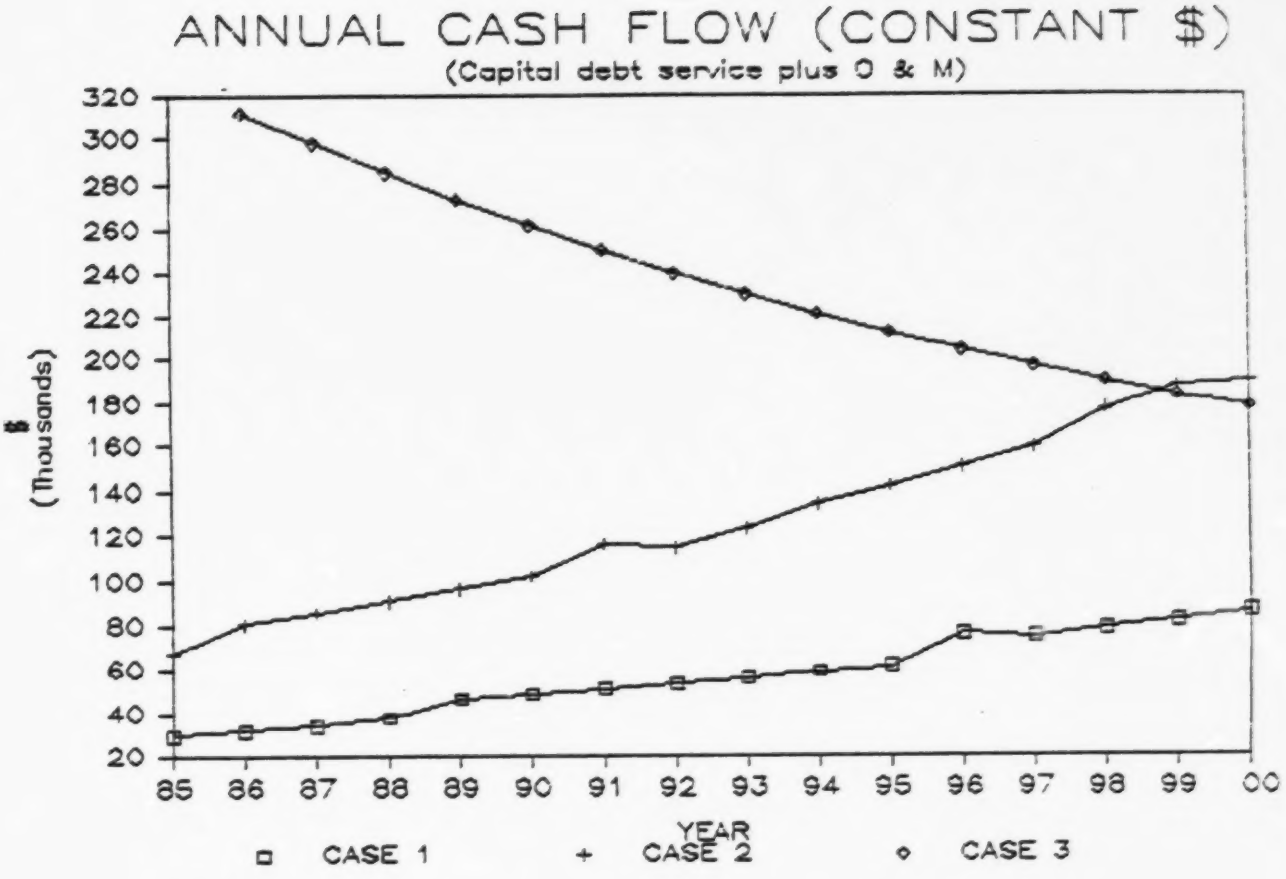
ENERGY EXCEEDENCE
SITE A

FIG 5



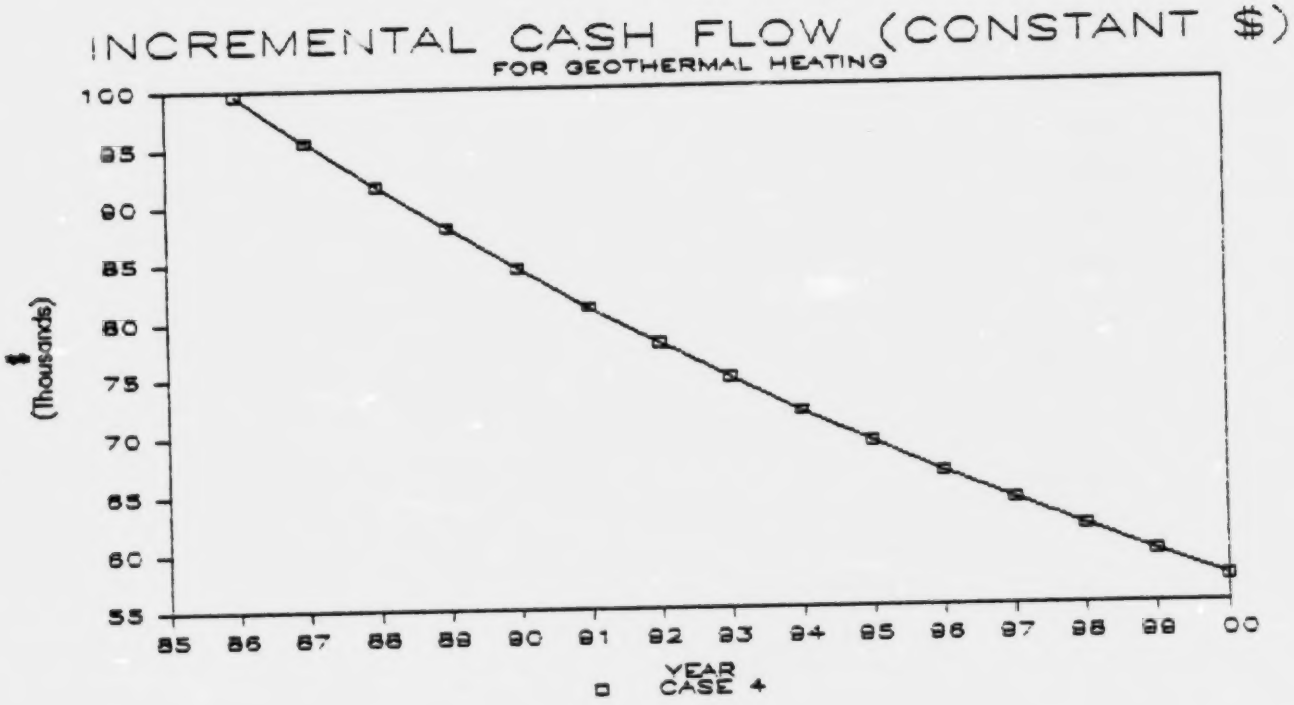
ENERGY EXCEEDENCE
SITE B

FIG 6



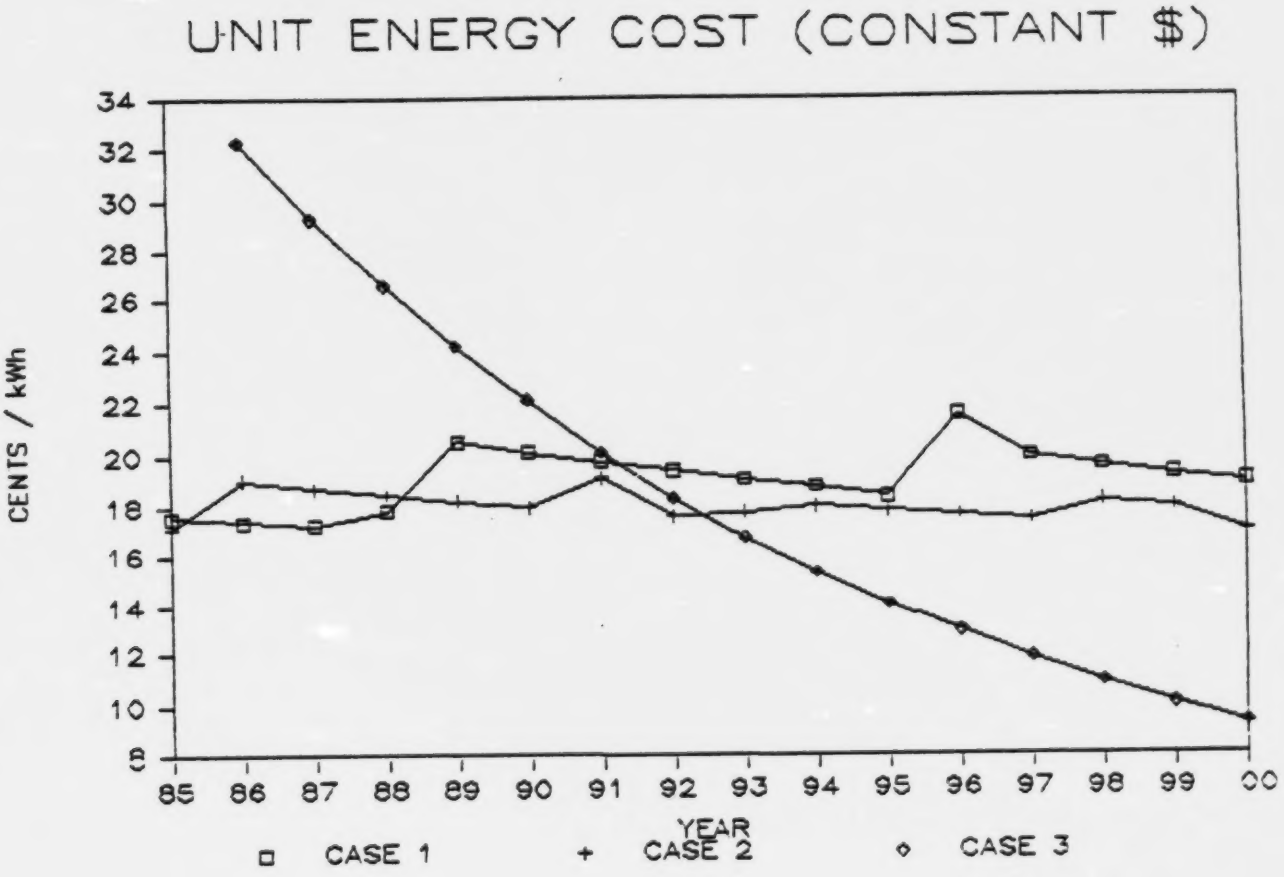
Case 1 Diesel - Load Restrictions - Firewood Heating
Case 2 Diesel - No Load Restrictions - Firewood Heating
Case 3 Hydro - No Load Restrictions - Electric Heating

Fig. 7



Case 4 Incremental Cost of Geothermal Heating

Fig. 8



Case 1 Diesel - Load Restrictions - Firewood Heating
Case 2 Diesel - No Load Restrictions - Firewood Heating
Case 3 Hydro - No Load Restrictions - Electric Heating

Fig. 9

APPENDIX A

TERMS OF REFERENCE

APPENDIX A to
Letter of 23 May 1984

Study of Energy Conservation Options
at
Hot Springs Cove Indian Reserve

Work Statement

1. Meet with the Band and explain the study to them and solicit cooperation for the energy audit.

2. Visit buildings in the community and assess opportunity for increased insulation of the individual structures to reduce heat losses.

3. Examine load management and identify the demand exerted by various appliances, lighting fixtures etc. The possibility of deferring loads such as water heaters to off peak hours will be considered.

4. Compile inventory of existing loads and review behavioural influence on existing loads.

5. Review the available data on the geothermal potential of Hot Springs Cove. Identify data required for detailed study of the geothermal resources. Evaluate methods of obtaining this data and prepare recommendations for carrying out a detailed study of the geothermal resource.

6. Review technologies for the recovery and use of the geothermal resource. Identify environmental considerations that must be considered. Recommend the most appropriate method of resource recovery and usage.

7. Evaluate land status of areas considered most consistent with geothermal production. Make recommendations for the acquisition of rights under the appropriate legislation.

8. Identify site(s) with small hydro potential. Summarize available information on the sites and assess suitability for future study.

9. Identify other potential renewable energy resources including biomass and wind.

10. Compare at a pre-investment level, conservation and each feasible energy resource on a cost benefit basis.

11. Meet with the community and present the results obtained. On the basis of comments from the community and Energy, Mines and Resources select the energy option for further study.

12. Establish the potential of the selected option to meet community energy demand.

13. Analyze community energy demand data, project load growth and identify most suitable sizing for the village power system.

14. Visit the community to further investigate site possibilities. Recommend monitoring of energy source(s) that would be required.

15. Meet with the community to outline progress of study to date. Obtain comments on the direction and progress of the study. Take comments into consideration in the remaining tasks.

16. Prepare a preliminary layout of the scheme and estimate capital cost. If further study is required give a detailed terms of reference for the additional work. If appropriate prepare circuit diagrams and select components.

17. Prepare draft report. Provide copies to the community and Energy, Mines and Resources. The draft report will include a comparison of the investment cost of a new source with continued operation of the existing diesel system.

18. Finalize draft report and provide six copies to the Band.

The Community will be required to:

1. Meet with the consultant and arrange for the consultant to have access to buildings in the community.

2. Arrange for the cooperation of Band members with the consultant.

3. Provide comments to the consultant as requested.

H. A. Hutchinson, P. Eng.
Director of Engineering

P. D. Plunkett, P. Eng.
Director,
Water Resources Division

Band Chief

Band Manager

Hesquiat Indian Band

APPENDIX B

A REPORT ON THE GEOTHERMAL POTENTIAL OF THE HOT SPRINGS COVE AREA, VANCOUVER ISLAND

A REPORT ON THE GEOTHERMAL POTENTIAL OF THE HOT SPRINGS COVE AREA, VANCOUVER ISLAND

by

Nevin Sadlier-Brown Goodbrand Ltd.

November 1984

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1. INTRODUCTION

1.1 Terms of Reference

As part of a study of energy conservation options at Refuge Cove, Nevin Sadlier-Brown Goodbrand Ltd. was retained by Crippen Consultants Ltd. to evaluate the potential for exploitable geothermal resources in the area. A well known hot spring at Sharp Point, the south tip of the Openit Peninsula on the west side of Refuge Cove (also referred to on some maps as Hot Springs Cove) has long been considered evidence of the presence of a geothermal resource. The precise location, size, temperature and chemical makeup of any such resource were never determined. This investigation however constitutes an attempt to resolve at least some of these questions by means of a methodical evaluation of all existing data on the hot spring and adjacent area, a field examination of the area of interest, sampling and analyses of spring water and gas, and preparation of a geological model consistent with the data obtained.

In addition to the foregoing we have also endeavoured to prepare a set of recommendations for development and utilization of the resource in the event that this option is found to be compatible with the requirements of the community at Refuge Cove.

1.2 Scope of Work

The study began with the compiling of all available references on the area of interest. These included geological reports and maps, analytical reports, topographic and bathymetric maps, and aerial photographs and surveys. This data was reviewed prior to a visit to the site on October 2nd and 3rd, 1984 at which time a meeting with the residents of the Refuge Cove village was held. Those present at the meeting were advised of the nature and rationale of the investigation and they were asked to contribute to it by providing additional information from observation based upon their experience in the area. On the day following the meeting, three sites were visited. Temperature measurements were taken and samples of water and gas were obtained and subsequently sent for analysis to Chemex Laboratories Ltd. of North Vancouver, B.C. The analytical results were evaluated and used to prepare estimates of temperatures at depth in an inferred reservoir and as an aid in establishing other geothermal parameters including the source of the water, the

most probable origin of the heat, and a probable site for the inferred reservoir.

Following completion of the field investigation a review of various methods for further investigation was conducted and a set of recommendations for continued exploration and development, environmental mitigation, and acquisition of geothermal rights was prepared. These recommendations were presented in summary form to the residents of the Refuge Cove Community at a meeting held November 21, 1984.

2. RESOURCE EVALUATION

2.1 Geological Setting

The area of geothermal interest is underlain by metamorphic, volcanic, and plutonic rocks and is traversed by a major north-south trending fault.

The oldest rocks comprise the West Coast Metamorphic Complex which is an assemblage of schists, amphibolites, metasediments, metavolcanics and intrusive rock, principally quartz diorite. These rocks form the peninsula west of Refuge Cove including Mate Islands as well as the southern portion of the Openit Peninsula. They are Paleozoic and Mesozoic in age and they host all of the known geothermal manifestations in the area.

The rocks of the West Coast Complex are intruded north of Refuge Cove by Jurassic granodiorite, quartz diorite, and granite which comprises the Island Intrusions.

Both the Island Intrusions and the West Coast Complex have been intruded by an irregularly shaped pluton of Tertiary age (32-36 my) termed the Hot Springs Stock (Muller et al, 1981). The Hot Spring Stock underlies the northern part of the Openit Peninsula and the region at the head of Refuge Cove as well as a one kilometre wide belt extending from there southwesterly to the coast.

A major north-northwesterly trending fault divides the rocks on opposite sides of Refuge Cove and is probably responsible for the topographic depression which creates both the inlet and the valley of the creek which empties into it from the north. From the head of Refuge Cove the fault extends northerly then northwesterly to the vicinity of Hesquiat Lake. In Refuge Cove it lies offshore within two or three hundred metres of the community.

Until recently the only geothermal manifestation known in the area was the Sharp Point Hot Spring which issues from fractured granodiorite approximately 200 metres north of the point at the southern tip of the Openit Peninsula. In 1975 however an airborne survey employing a heat sensitive infra-red scanner was performed on behalf of B.C. Hydro and Power Authority (NSBG, 1975). This survey identified a small but distinct heat anomaly near the head of a small inlet on Mate Island. A follow-up field examination did not reveal any geothermal explanation for the anomaly but attributed it to a nearby pond of surface water a few degrees above the ambient temperature though distinctly warmer than the ocean water with which it was being compared by the scanner. A re-examination during the course of the present investigation, however, has now confirmed that a warm spring is present at the site and is the source of the IR anomaly. Except at low tides however it is underwater which may be why it eluded discovery in 1975.

Approximately 100 metres off the south shore of Mate Island is an underwater gas vent which produces a bubble patch about 2 metres in diameter. Fishermen and local residents have known of the phenomenon for years and it was drawn to the writer's attention by several band members in response to a request for information on geological features which may be related to geothermal activity.

The three geothermally interesting features, namely the hot spring, the warm spring, and the gas vent are all hosted by rocks of the West Coast Complex and are clustered within a kilometre of one another near the projected submarine extension of the Refuge Cove fault.

2.2 Observations and Analytical Data

The Sharp Point Hot Spring issues at a temperature of 50.5°C from a fracture in quartz diorite approximately 12 metres above high tide level. The fracture dips steeply to vertically and strikes at 110°. The water in the spring appears to contain a considerable gas component and bubbles profusely in the general vicinity of the vent. Its pH was found to be 6.5-7 and its conductivity 1230 uMhos. The spring has been examined and sampled on several occasions in the past and analytical results from the present examination are essentially consistent with these previous determinations as shown in the table below.

TABLE 1: ANALYSES OF FIVE SAMPLES OF SHARP POINT HOT SPRING WATER

	Concentrations of P.P.M. Sharp Point Hot Spring				
Major Constituents	CLAPP (1913)	SOUTHER (1975)	NSBG (1975)	NSBG (1981)	NSBG (1984)
Cl	217	206	224	150	212
Na	137	141.2	144	150	170
Mg	1.0	.05	.05	1.5	<0.1
S	-	-	-	-	-
Ca	20	17.7	16.5	17.0	16.0
K	2.0	2.0	2.1	1.50	2.0
Br	-	-	-	-	-
C	-	-	-	-	-
Sr	-	.01	2	-	-
B	-	-	20	2.20	1.20
Si	-	25	23	-	104
F	-	1.3	-	11.0	1.16
SiO_2	59	52.8	49.0	36.0	24.0
SO_4	47	36	28.5	33.0	29.0
HCO_3				21.7	
Li				<0.05	0.08
Fe				0.060	<0.02
Hg				0.3	
Rb				1.20	
Mn				0.010	<0.02

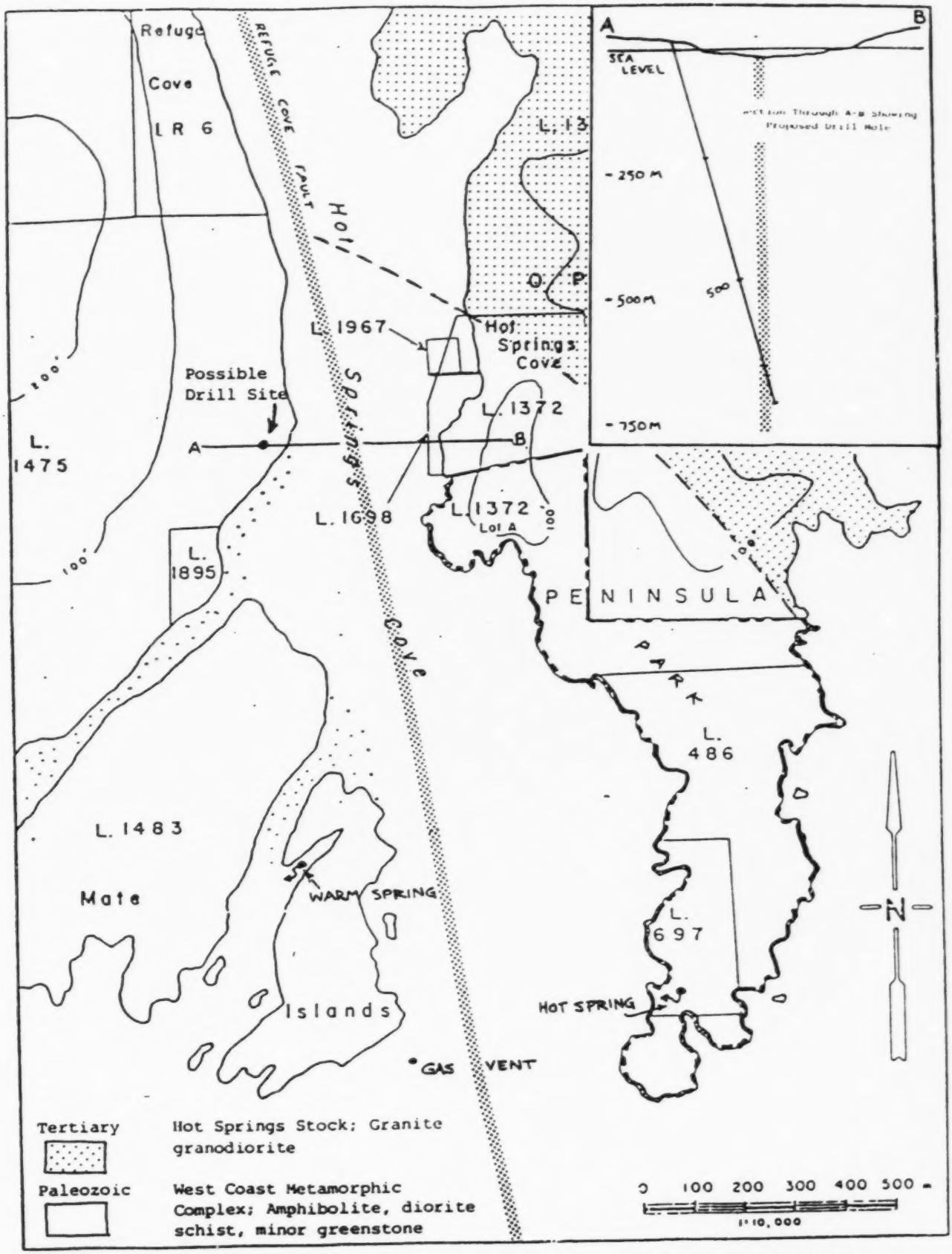


FIGURE 1: Summary Geological Sketch and Land Status Map of the Refuge Cove Area.

The analyses indicate that the hot spring water is characterized by sodium chloride and a moderate SiO_2 content.

The values in parts per million of the concentrations of various elements dissolved in spring water may be applied to several empirical equations to derive an estimate of the maximum temperature to which the water may have been heated in the geothermal system. Three formulas (Fournier and Truesdell, 1970; 1973; and Nieva and Nieva, 1982) incorporating values for dissolved Na-K-Ca, Mg and SiO_2 were applied to the analytical results from the Sharp Point Hot Spring. Temperature estimates produced by the three equations and five sets of sample data are given in Table 2.

TABLE 2 **Cation (Na,K,Ca,Mg) and Silica Geothermometry Sharp Point Hot Spring**

Designation	Est.Temp.° (F&T)	Est.Temp. (N&N)	Est.Temp (SiO_2)
Clapp (1913)	93.0	75.5	110
Souther (1975)	93.1	108.2	105
NSBG (1975)	94.7	109.4	101
NSBG (1981)	82.0	80.0	88
NSBG (1984)	89.3	113.2	70.6

Temperature estimates at depth in the Sharp Point geothermal system range from a low of 70.6°C to a high of 113.2°C with the average for the fifteen calculations being 94.2°C. These values are intended only as estimates but are considered consistent with a reservoir temperature ranging between 90 and 105°C.

Gas samples were obtained both from the hot spring and from the submarine vent off Mate Islands. They were analyzed using a gas chromatograph by Cantest Ltd. of Vancouver, B.C. Analytical results are given in Table 3 below.

TABLE 3

Location	Nitrogen (%)	Oxygen (%)	Methane (%)	SiO_2 (ppm)	Hydro carbons (ppm)
Sharp Point Spring	91.73	8.13	0.14	57.8	34.8
Mate Islands Gas Vent	88.41	10.78	0.60	2100	73.4

An interpretation of these results is given in Section 2.3.

The Mate Island warm spring issues from gravel near the north end of a shallow northerly trending inlet on Mate Island. It is about 500 metres north-northwest of the gas vent and less than 900 metres northwest of the Sharp Point Hot Spring but on the opposite side of Refuge Cove. The source which was in about 1.5 metres of water at the time of the visit could be identified by the presence of gas bubbling from the gravel. It was not possible to obtain meaningful water or gas samples but a temperature probe was placed on the bottom in the immediate vicinity of the vent. The temperature here was found to be 20.5°C which is 6.5°C above the 14°C ambient temperature of water in the inlet.

2.3 Discussion and Conclusions

The hot springs and the gas vent in the vicinity of Sharp Point and Mate Islands all issue from fractured crystalline and metamorphic rocks of the West Coast Complex. This, along with their proximity to one another and the chemical similarities between the Sharp Point and Mate Island gas samples, suggests a common origin. Possible water sources are as follows:

1. Meteoric water (rain and snow) derived from the mainland north of the spring area
2. Ocean water
3. Connate water from an adjacent sedimentary basin
4. Juvenile or magmatic water

The evidence gathered to date tends to favour a meteoric source for the water. This evidence is incomplete and could be enhanced by isotope studies and additional geochemistry. However both water and gas analyses, as well as geological observations are consistent with a model whereby meteoric water collected in a drainage basin comprising some $7km^2$ immediately north of Refuge Cove is conducted to depth in a zone of permeability produced by the Refuge Cove fault. It is then heated, transported laterally and vented through cross-fractures and/or splay faults in the crystalline rocks a few kilometres to the south.

The meteoric model most readily explains the gas composition. Nitrogen and oxygen are generally uncommon in most geothermal systems. They are, however, abundant in air

comprising respectively about 78 and 21% by volume. In this model air, which is dissolved by surface waters is carried into the system, held in solution by high pressures at depth then liberated when the water approaches the surface in the vent areas. The depletion, by about 50%, of the oxygen in the gas samples shown in Table 3 is best explained as the result of consumption through oxidation of various rock components within the geothermal system.

Possible sources for the heat are as follows:

1. Deep circulation in a region of normal geothermal gradient (approximately 25°C/km).
2. Shallow to intermediate circulation in an area of elevated geothermal gradient.

As the geothermal gradient in the area is presently unknown neither of these possibilities can be confirmed. Nevertheless the second - shallow to intermediate depth circulation - is tentatively favoured with the heat being generated by natural nuclear decay most probably occurring in radioactive elements constituent in minerals within the Hot Springs Stock. (This argument may also apply to the warm spring near Ahousat on Flores Island whose waters may be circulated through faults cutting a Tertiary pluton genetically related to the Hot Spring Stock.)

Assuming that the temperature estimates resulting from the geothermometry plus all or part of the foregoing arguments are valid the following conclusions are offered:

- The Refuge Cove fault and fracture systems related to it constitute the most probable site for the geothermal reservoir from which the Sharp Point hot springs issues.
- It is unlikely that any local reservoir is at a high enough temperature to be considered for use in direct thermal electrical generation.
- The temperatures may be consistent with thermal electrical generation using a binary cycle system employing a vapour turbine and condenser.
- The temperatures and fluids may be compatible with direct use and space heating applications.

- It appears possible that hot water might be extracted from wells drilled close enough to the community to be of economic value.

3. RECOMMENDATIONS FOR FURTHER INVESTIGATION

3.1 Data Requirements

Utilization of the geothermal resource in the Refuge Cove area will be dependent upon a number of factors. Of these the most critical are as follows:

1. Reservoir location and depth
2. Reservoir temperature
3. Geothermal fluid chemistry
4. Reservoir pressures and flow rates
5. Methodology and economics of utilization
6. Environmental considerations

The data on hand including analytical results and reservoir temperature estimates provide useful guides to the possible nature of a geothermal resource in the Refuge Cove area. They are however derived at the surface from springs, and vents which are essentially leaks from the reservoir. The samples may have been subjected to cooling or dilution and may not accurately represent the true nature of the fluid at depth. This and other subsurface conditions can only be determined by drilling a test hole. This will allow studies of subsurface geology, temperature measurements at depth, heat conductivity measurements at depth, gradient and heat flow calculations, and possibly sampling and analyses of reservoir fluids. If a reservoir is intersected, information on additional physical characteristics may also be obtained.

3.2 Evaluation of Investigation Methods

A wide number of investigative methods may be employed in geothermal exploration and development. Electrical exploration methods, resistivity in particular, have proved useful in delineating potential geothermal reservoirs elsewhere in British Columbia. At Refuge Cove however the proximity of seawater to the inferred reservoir area may be expected to eliminate or at best severely restrict resistivity as a useful exploration method. The appropriate methods for continued investigation of the geothermal potential of the Refuge Cove area are as follows:

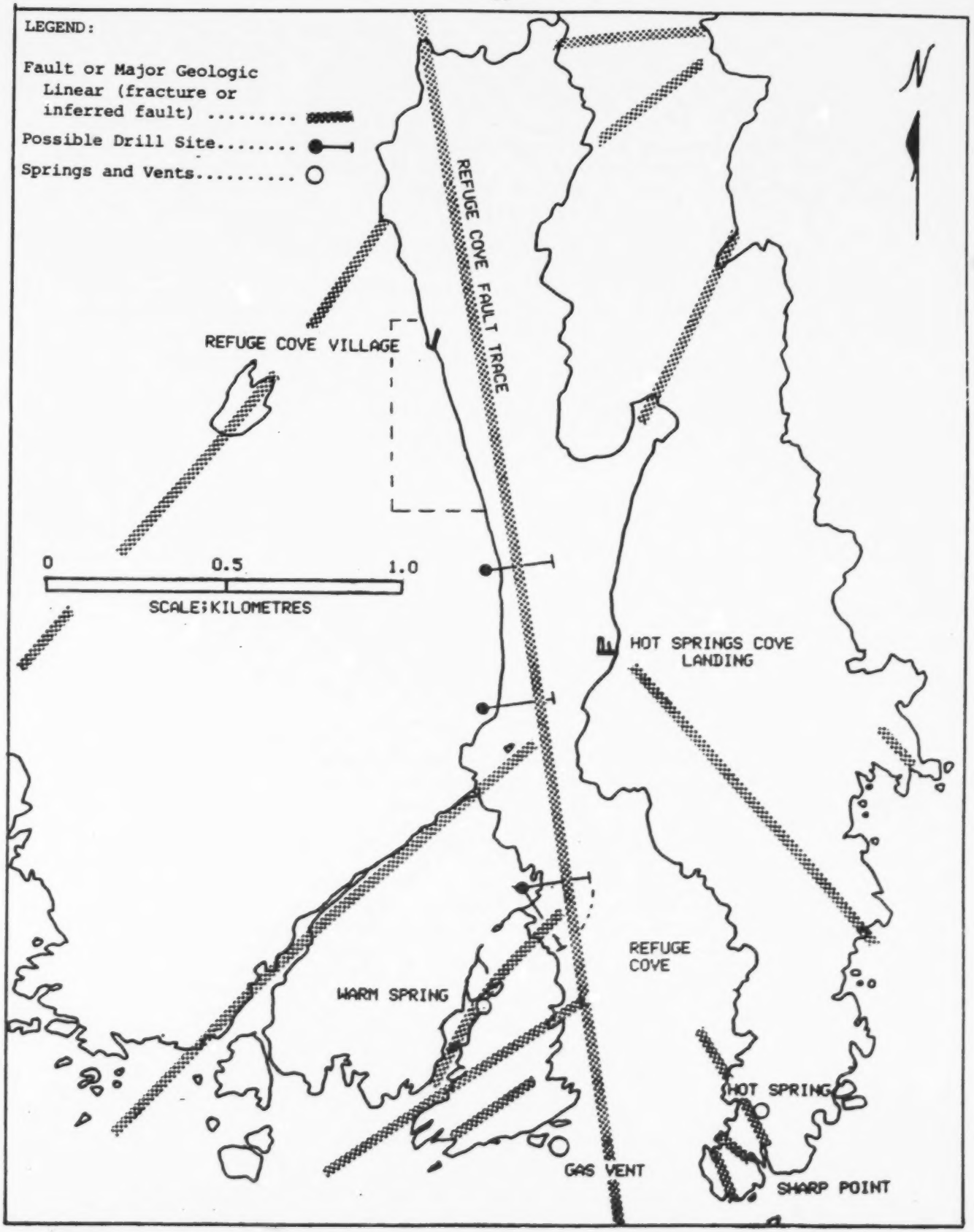
1. Detailed geological mapping.
2. A reconnaissance soil geochemical survey of the area west of the Cove. A limited reference survey should be performed in the hot spring areas. Samples should be tested for mercury and arsenic.
3. Additional sampling and chemical analyses of the three known or supposed geothermal manifestations in the area. This might include isotope studies which could provide additional information with respect to the source of the geothermal fluid and its reservoir residence time.
4. Geothermal test hole drilling. Depending upon geology, access, terrane, and availability of equipment this may be done using either diamond drilling or rotary drilling equipment. On a project such as might be envisioned for Refuge Cove diamond drilling is favoured. Reasons are:

   a) Diamond drilling provides drill core which permits accurate downhole geological observations.
   b) Diamond drill setups are generally smaller and less elaborate than those required for the other types of drilling equipment.
   c) Diamond drills tend to be comparatively light and are transportable in smaller units than the other types of drilling equipment. These are particularly advantageous in features in roadless areas.

3.3 Review of Technologies for Recovery and Use of Geothermal Resources

Geothermal energy may be economically recovered from naturally heated steam or hot water which is used to drive steam turbines for electrical generation and to provide heat for many other applications. For a few of these sufficient heat may be obtained from natural springs but for conventional industrial use the resource must be tapped at depth by drilling.

Geothermal production drilling employs equipment similar to that used in the oil and gas industry although minor modification may be necessary to compensate for corrosive fluids or high temperatures.



REFUGE COVE GEOTHERMAL STUDY AREA: ALTERNATIVE DRILLSITES AND MAJOR LINEARS
FIGURE 2

To produce and utilize geothermal energy production holes must be connected to a gathering system which pipes the geothermal fluid from the wells to the point of utilization. If the geothermal fluid is dry steam it may be piped directly to turbines for electrical generation. High temperature water may be directed to a separator and flashed to produce both steam and hot water. The steam may be used to drive turbines and the hot water possibly flashed again at a lower pressure, used for another purpose, discarded, or reinjected into the reservoir.

Low temperature geothermal fluids may be used to generate electricity by means of a binary cycle turbine. More commonly however they are used directly. Direct applications include space heating, process heating, (such as drying, cooking, or chemical production) or in agriculture, aquaculture and recreation.

Possible applications for the resource under discussion might include:

- electrical generation employing binary cycle turbines,
- space heating
- aquaculture
- silviculture

3.4 Recommended Approach

The existing data on the geothermal potential of the Refuge Cove area is not sufficient to permit a valid selection of the appropriate method of utilization. It tells us only that an exploitable resource may be present. In our opinion however it would be in the best interest of the client to initiate a phased program intended to discover the nature of the resource. The initial requirements will be pertinent data respecting factors 1 through 4 as listed in Section 3.1 on data requirements. These factors, namely reservoir location, temperature, chemistry, and physical characteristics will only be resolved through test drilling probably in more than one hole. With this objective in mind then our recommended approach is as follows:

1) Provide funding for drilling of at least one geothermal test hole and performance of related technical activities in accordance with the cost estimate set forth below. The client should recognize the risk inherent in an

exploration program of this nature and ensure that this is taken into account in the method of funding - possibly by sharing the cost with other interested parties.

2) Take steps to acquire geothermal rights to the resource area.

3) Initiate permitting process for drilling and drill related activities.

4) Prepare a geological map of the area of interest. Particular emphasis should be placed on identification of structural features which may affect distribution of geothermal fluids.

5) Carry out limited soil geochemical surveys to test potentially productive structures. (This work may not be justified if the proposed drill target is constrained by economic and/or physiographic considerations.)

6) Plan, site, and drill the test hole in a manner consistent with provincial requirements and carry out all related technical activities including temperature and lithological logging, fluid, and rock sampling and testing, etc. If possible the hole should be completed in a manner which will permit fluid samples to be obtained and allow continued production at a modest scale (a rate of 1 or 2 litres/second would be consistent with a hole of this type. This scale might be compatible with aquaculture or space heating depending upon the resource temperature).

The principal objective, as presently envisioned, is to test a segment of the Refuge Cove fault or splay faults branching from it within or near the West Coast Terraine south of the village. The precise location of the drill site should be determined from geological and topographical data which has yet to be obtained. Most probably, however, the target structure would most effectively be intersected by a high angle hole drilled easterly from a site near the shore between the village and Mate Islands, possibly on Mate Islands. A hole to the order of 750 or 800 metres in length should suffice to test the inferred structure. Data obtained from this hole would be used in deciding whether or not an exploitable resource is present and, if it exists, which of several possible methods of utilization would be the most appropriate. An estimate of the cost of carrying out the project to this decision point is as follows:

Permitting and preparatory costs	$ 6,000
Preliminary geology & geochemistry	3,000
Mobilization and demobilization (truck and barge)	3,500
Standby during transit	4,000
Site Preparation	3,000
Blow out Prevention System	2,000
Valves and casing	12,000
Drilling (800m @ $95/m all in)	76,000
Water sampling and analyses	500
Geology and engineering (55 man-days @ $300/md)	16,500
Camp costs (meals and accommodation) (200 man-days @ $30/md)	6,000
Cook (35 days @ $100/diem)	3,500
Administration	3,000
Evaluation and report preparation	6,000
Total	$145,000

Notes to Cost Estimate

1. Costs are based upon approximate rates as follows:
   Rig - Longyear 44
   Drilling - HQ from 0 to 450m and NQ from 450 to 800m - $79/m
   Reaming - $85/hr
   Reaming Shell - $13/m
   HW Casing - $50 to $65/m

2. Mobilization at cost

3. Room and board supplied

4. Drilling 2 or 3 shifts - 24 hours

5. Transport:
   Barge from N.Arm of Fraser River to site (scheduled monthly tour) or truck to Tofino and barge - approx. 25 tons of material.

6. Land acquisition and rental costs have not been included as they may vary subject to approval of the Lieutenant Governor in Council for the Province of B.C.

7. Provision for contingencies has not been included. An

allowance to the order of 10-15% of the total budget would be appropriate for a project of this nature.

The drilling program outlined above is considered the optimal approach to the problem at hand. It would provide the technical information necessary for continued resource development and, in addition, might be used to produce hot water in amounts sufficient for many economic applications. Other alternative courses of action are, however, available.

One alternative which might, in the short term be less costly than the program described in the foregoing would be to drill several (up to three) shallow holes intended specifically to obtain physical and geological data and not for recovery of fluids. A cost reduction of 30-40% could be envisioned but there would be a number of disadvantages. Among these are:

1. No data on reservoir fluid would be intentionally acquired.
2. Fluid control and disposal problems could result if a productive zone were encountered.
3. After completion the hole would have no further use.

The cost of such a program would equate approximately to a "dry hole cost" for the first option or to the order of $100,000. As an approach to geothermal exploration this option would actually be a more conventional first phase of exploration than the first drilling alternative.

The data obtained from this work would be used in conjunction with additional geological and geochemical information as an aid in siting a production scale well or, if gradient measurements warranted, retrofitting and deepening an existing hole.

A second alternative approach might be to carry out intensive geological, geochemical and possibly geophysical studies with the objective in mind being discovery and delineation of the surface expression of any on-shore structures which may control distribution of geothermal resources. Splay faults associated with the "Refuge Cove Fault" are possible examples of such features. The resource would still have to be confirmed by drilling at a future time but if a viable target were to be discovered this alternative would provide a number of overall advantages to the project.

Among these are:

1. Lower drilling risk as background technical data would be available.
2. Drilling costs might be reduced as an on-shore-target could probably be tested by a shorter hole.
3. Drilling problems and costs might be reduced as an on-shore-target would not require directional drilling.
4. Exploration would be phased with low front end costs and more accurate estimates of downstream (drilling) costs and problems.

An estimate of the cost of carrying out the geological, geochemical and geophysical surveys envisioned for this option is to the order of $34,100 broken down as follows:

Planning and Orientation	$ 1,200
Geological mapping	7,200
Geochemical sampling (16 line km)	2,500
Geophysical Reference Survey	4,000
Meals and accommodation	1,900
Transportation & Mobilization (plane, boat, truck)	3,200
Geochemical analysis (400 samples) (Hg, As, Ra(?))	4,500
Evaluation & reporting	3,200
Administration & communications	2,000
Contingency allowance 15%	4,400
Total	$34,100

4. ENVIRONMENTAL CONSIDERATIONS

The leading environmental considerations which may apply to the geothermal exploration and development work envisioned for the Refuge Cove area are as follows:

1) Mitigation of surface damage caused by drilling and access.

2) Control of drilling fluids and additives.

3) Control and disposal of reservoir fluid.

4) Effect on existing recreational resources.

With respect to Items 1 through 3 procedures for environmental protection are stipulated in the regulations attached to the B.C. Geothermal Resources Act, the Forest Act, the Land Act, and possibly the Pollution Control Act. Adherence to these requirements is straight-forward. It is important to ensure, however, that both exploration and development budgets provide for environmental considerations from the outset of any project.

Item 4 above refers to the possible effect that exploration activities might have on the hot spring at Sharp Point. There is evidence that this hot spring as well as the Mate Islands warm spring and the gas vent offshore near Mate Island, are derived from a common reservoir. Although the size of this reservoir and its productive capability are unknown it is possible that extraction of reservoir fluid from a drillhole could affect flows at one or more of these three known natural sites. As far as exploration drilling is concerned no adverse effects are anticipated provided drilling is done in a manner which would permit the hole to be permanently sealed if required. If production from the reservoir were found to have an adverse effect on the existing flow rate at the Sharp Point Hot Spring and/or other natural vents it could be necessary to restrict fluid extraction from any well or wells to a level consistent with satisfactory sustained flow at the natural spring. We emphasize, however, that this is strictly a consideration because at present there are no data to accurately predict the effect of drilling in the inferred reservoir.

5. LAND STATUS

5.1 Legislation and Legal Considerations

Geothermal resource exploration and development in British Columbia is controlled by the Geothermal Resources Act which was assented to on June 7, 1982. The Act stipulates the method of acquisition of geothermal rights and, in an attached section, sets forth regulations for geothermal drilling and production. Administration of the Act is the responsibility of the B.C. Ministry of Energy Mines and Petroleum Resources.

Additional legislation which may effect geothermal rights in this and other areas in B.C. include the Petroleum and Natural Gas Act, the Land Act, the Mineral Act, and the Forest Act.

5.2 Acquisition of Geothermal Rights

The procedures for acquisition of geothermal rights under the B.C. Geothermal Resources Act have been summarized by Acres/NSBG (1984) as follows:

> "A permit is needed for the exclusive right to explore for geothermal resources. The minimum area for which a permit may be issued is a "block" which consists of an area bounded by 5 minutes of latitude and 7 minutes 30 seconds of longitude. Blocks are tied to geodetic latitude and longitude and so have only a coincidental relationship to the actual location of a resource. Permits are awarded by a system of competitive bidding, by sealed tender, only on blocks that have been publicly posted. In order to get blocks posted for bidding, prospective developers must ask the Petroleum Resources Division to post them. Tenders must include a work program and cost estimates describing the type and extent of work that is proposed for the exploration area. Permits are awarded on the basis of which geothermal program is, in the Minister's opinion, the best. The permit costs $500 plus an annual rent of $1.00 per hectare. (The number of hectares in a block varies with latitude: at 50°N a block has about 8,300 hectares). Only blocks can be rented but only part of a block need be explored.
>
> Approximately one week after being awarded a permit the permittee must provide a performance deposit equal to the accepted work tender. The work obligation represented by the deposit will be reduced annually on the basis of the approval of an affidavit of expenditure and supporting exhibits. Failure to meet the committed work obligations may result in the forfeiture of the performance deposit. Payments may be made in lieu of work done.
>
> The Act presumes most exploration will be done by drilling and consequently has extensive provisions for drilling test holes and wells. All drilling rigs must have a rig license issued under this Act or the Petroleum and Natural Gas Act. All cores and samples of cuttings from wells must be sent to the Division's Charlie Lake office at Fort St. John. During testing of blow-out prevention equipment, drilling crews must be supervised by

personnel with supervisory certificates issued within the past 3 years by the Petroleum Industry Training Service. Daily reports, well summaries, well histories, and workover reports must be filed for all wells drilled. Reporting requirements for test holes are less rigorous. While actual drilling is covered in detail, only very brief regulations apply to disposal of drilling and production material, and well testing procedures. In order to conduct exploration by means other than drilling, one must notify, in writing, the commissioner of the titles branch of the Petroleum Resources Division.

In order to convert a permit to a lease, the permittee must submit a development plan for approval by the Minister. Leases are valid for 20 years and may be renewed. Neither lease rental rates nor royalty rates for geothermal production have been set, nor has any method of calculating the royalties been defined. Both the method and rates are to be determined by the Lieutenant Governor in Council (ie. the Provincial Cabinet). The Minister is empowered to bind developers into a unitization agreement."

In the area presently considered to be of geothermal interest the surface has been subdivided as follows: IR#6 (Refuge Cove), Lot 1474, Lot 1475, Lot 1483, and Lot 1895. The land lots lie within the Calyoquot land recording district which is administered by the B.C. Assessment Authority office at Port Alberni. As no record of ownership for the four lots could be produced by the Assessment office it is assumed that they are Crown land and, except where affected by an existing mineral claim, are available for both surface and subsurface leasing.

In the southern part of the area of interest mainly on lot 1483 which covers Mate Islands is a two unit mineral claim known as the Alto 1 claim (Record No. 504). The claim is held in the name of Alto Exploration Ltd. and is in good standing until July 26, 1985. Rights to subsurface minerals within the claim area are therefore held by Alto Exploration Ltd. Geothermal resource rights are not included in mineral claims but the claim owners may be entitled to certain prior rights which should be ascertained before carrying out any geological work on staked land.

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